The Proceedings of the Iowa Academy of Science

Volume 93 | Number

Article 6

1986

Quaternary Biostratigraphy and Paleoecology of Fossil Mammals from the Loess Hills Region of Western Iowa

R. Sanders Rhodes II
University of Iowa

Holmes A. Semken Jr.
University of Iowa

Proc. Iowa Acad. Sci. 93(3):94-130, 1986

Quaternary Biostratigraphy and Paleoecology of Fossil Mammals from the Loess Hills Region of Western Iowa

R. SANDERS RHODES II and HOLMES A. SEMKEN, JR.

Department of Geology, University of Iowa, Iowa City, Iowa 52242

Iowa Quaternary Studies Group Contribution No. 4

For over 115 years the Loess Hills region of western Iowa has furnished the fossils of Ice Age and recent mammals to both amateur and professional paleontologists. The oldest of these fossils (the "Aftonian fauna") predates the last glaciation and predominantly are the remains of large mammals. These sites are poorly understood but probably date from near the Irvingtonian/Rancholabrean boundary at about three quarters of a million years ago.

The last glaciation (Wisconsinan) is represented by 3 micromammal-dominated faunas and scattered finds of individual specimens of large mammals. Taken together, these indicate rather open grassland, with scattered boreal forest groves which became more dense toward the end of the glaciation. Although cold by present-day standards, the climate must have been unlike any in North America today because the taxa are not now found living in association.

The post-glacial (Holocene) began about 10,000 years ago and saw tremendous change in Iowa's fauna from the preceding Wisconsinan. Although no faunas are reported from the Loess Hills in the first two and half millennia of the Holocene, this period contains the extinction of the Pleistocene megafauna and the climatic warming which led to extirpation from the state of the more boreal micromammals. The rest of Holocene is represented by 20 sites, both paleontological and archeological, which document a smaller scale, but still distinctive, pattern of climate change. The foundations of this prehistoric record have been established but much work remains to be done to realize its potential as a predictive tool for future climatic change.

INDEX DESCRIPTORS: Fossil mammals, Aftonian, Wisconsinan, Holocene, Zooarcheology, Paleoecology, Paleoclimatology.

Since Leidy's report of fossil muskox in 1870, both amateur and professional paleontologists have found the Loess Hills Region (Prior, 1976; Farrar et al., 1985) of western Iowa to be a fertile source of fossils representative of a diverse, now partially extinct, mammalian fauna of Late Quaternary (Ice Ages and Recent) age. The bones and teeth of large and small mammals have been found both in archeological and non-cultural contexts. Sand and gravel pits, quarries, road cuts, and stream-eroded banks have surrendered most of the non-cultural specimens. Those specimens found in place largely have been recovered in alluvium from old stream channels. The loess itself occasionally has produced the remains of isolated individuals. All collections made from pumped or dredged pits have been excluded from consideration because it is impossible to determine the exact stratigraphic occurrence of the fossils. However, many specimens have been collected from spoil piles in "dry" pits and on gravel bars in modern streams. Although their exact ages and stratigraphic occurrence also are unknown, most are believed to be Wisconsinan (the last glaciation) in age.

Modern habitat requirements and centers of distribution of surviving species can be used to partially reconstruct the prehistoric climates of western Iowa. Therefore, a summary of all major known sites from both the Loess Hills and nearby western Iowa (Fig. 1), discussed in chronologic order from oldest to youngest, is appropriate for this study. A useful catalog of major sites elsewhere in Iowa is found in Fay (1978a). Lundelius et al. (1983), Semken (1983), and Semken and Falk (in press) relate many of these sites to the larger context of the Upper Midwest and the United States. Precise locality data is available in the primary sources cited below. The scientific (Linnaean) names and their vernacular equivalents for all mammalian taxa are listed alphabetically in Appendix A.

OLD TILL AND OLD BONES: FAUNA OF THE LOESS HILLS PRIOR TO LATE WISCONSINAN

Although the subject of several publications in the early 1900's, the mammal remains of pre-Wisonsinan deposits have since received little study. Even though professionally evaluated at the time, the taxonomy of the fossils should be revised to follow modern nomenclature and the fossil-bearing horizons must be correlated into the substantially refined litho- and chronostratigraphic sequence of the Midwest Pleistocene (Ice Age).

The "Aftonian" Fauna: A History and Evaluation

The so-called "Aftonian" fauna is particularly perplexing. Discovery of this fauna was announced by Shimek (1908) and it was subsequently described by Calvin (1909a) from 10 distinct localities (some were multiple excavations) in western Iowa. Additional specimens (and more localities) were added to this fauna by Shimek (1910a), Calvin (1911), and Hay (1914). Later finds from these localities were described by Clement (1932). Faunal lists of varying completeness were presented in Calvin (1909a, 1911), Shimek (1910a), Hay (1914), Dechert (1968), and Frankforter (1971).

The fossils at all these localities were found in fluvial sands and gravels described as occurring between two glacial tills, designated as "Nebraskan" (below) and "Kansan" (above), and were exposed in wells, quarries, and (rarely) cutbanks along rivers. The fluvial sediments were correlated with the "Aftonian" sands and gravels of south central Iowa for two reasons. (1) The Loess Hills localities were outside the Wisconsinan glacial limit and the intertill sediments therefore were pre-Wisconsinan. (2) At all localities where till was preserved and had not been oxidized, the overlying till was light grey ("ashen blue" Kansan of Shimek, 1910b) and the underlying till was dark grey to black ("dark blue-black" Nebraskan of Shimek, 1910b). This till/gravel/till sequence was identical to that exposed in the type area of the "Aftonian" in south central Iowa to all outward appearances (Calvin, 1909b; Shimek, 1909; 1910a). Although other lithologic characters also were used, the color differentia were most obvious and widely applied. This correlation was questioned as early as 1934 by geologists working just across the Missouri River in Nebraska (Lugn, 1934:334-339).

Kay (1928) summarized the complex history of the early development of the lithostratigraphic interpretation, nomenclature, and usage in Iowa. The term "Kansan" was first used by Chamberlin (1895a), and he applied it to the lower till in the vicinity of Afton and Thayer, Union Co., south central Iowa. The investigations of, and

field excursions with, Bain (published 1897 and 1898) and Calvin (published 1905), prompted Chamberlin (1896) to transfer "Kansan" to the upper till of the Afton/Thayer area in agreement with their correlations to eastern Iowa. The concept of a type section had not been developed at that time but most modern researchers consider this Afton/Thayer area to be the type locality for the "Kansan" (Ruhe, 1969:26). Chamberlin (1895b) also was first to use the term "Aftonian." He considered the gravels between the two tills in the Afton/Thayer region to represent the "best exposures" available of this interglacial horizon (see also Bain, 1898; Calvin, 1905; Kay, 1928). Thus, this region is unequivocally the type area of the "Aftonian." The lower till in the Afton/Thayer area (subsequent to Chamberlin's, 1896, reevaluation of the usage of "Kansan") was called "sub-Aftonian" until Shimek (1909; 1910c) designated it "Nebraskan" by correlation from typical outcrops in the Omaha/Council Bluffs area of Iowa and Nebraska. A one-to-one correlation of the tripartite till/fluvial sediments/till sequence was made from western Iowa to the type area of the lithologic "Aftonian" in south central Iowa and the mammalian fauna thus was named "Aftonian" after its containing sediment (Calvin, 1909a; 1910; 1911; Shimek, 1908; 1910a; 1910b). The lithostratigraphic interpretation in the type area of the "Aftonian" thus was critical to the correlation.

This correlation is now suspect for three reasons. First, at several of the "Aftonian" fauna localities the fossiliferous sediment does not lie between two tills. Indeed, both Calvin (1911) and Shimek (1910a) noted that the Denison locality, Crawford Co. (Fig. 1, 11), was covered by loess (if even by that), not till. This indicates that the locality is probably in a Boyer River terrace; where radiocarbon dated, similar western Iowa alluvial terraces are of Wisconsinan age. Thus the lithostratigraphy at individual sites may not substantiate an "Aftonian" position and this suggests that the fossils from such sites should be excluded from the "Aftonian" fauna.

Second, the physical correlation of the western Iowa "Aftonian" gravels to the lithostratigraphic type area has long been questioned. Initially the debate centered on the depositional origin of the type "Aftonian" deposits in the Afton/Thayer region and their alleged correlatives elsewhere in Iowa and Nebraska (Kay, 1928; Lugn, 1934). Conceptually, the "Aftonian" interglacial was understood to be represented by either or both a weathering zone, which these workers termed the "Nebraska gumbotil" (Kay and Apfel, 1929:163-171), and associated unfossiliferous swale-fill sediments. Based on initial (and inadequate) models of interglacial climates and processes, these early researchers questioned the origin of the intertill gravels: were they waning "Nebraskan" glacial outwash, "Aftonian" interglacial alluvium, or "Kansan" proglacial outwash and "inwash" (Kay and Apfel, 1929:193-195). For researchers working in Nebraska (Lugn, 1934; Schultz, 1934) the most attractive alternative was at first early "Kansan." As examination of the Nebraska lithostratigraphic sequence developed, the Iowa "Aftonian" deposits were assigned to as young an age as "Late Pleistocene" (Schultz and Stout, 1948:567). Over the past two decades, strategically located drillholes and modern lithologic analyses have demonstrated the presence of at least 7 pre-Wisconsinan tills in western Iowa and eastern Nebraska (Reed and Dreeszen, 1965; Boellstorff, 1973a; 1978; G.R. Hallberg, pers. comm., 1984). Fluvial sands and gravels are known to separate these *tills* at some localities, and neither the fluvial sediments nor the tills are easily distinguished by field methods. Thus any attempt to correlate tills and intertill deposits must depend upon three-dimensional lithostratigraphic mapping in conjuncton with detailed laboratory analysis (e.g. Boellstorff, 1978). The correlations of Shimek, Calvin, and other early workers therefore could only be correct by accident. Furthermore, great conceptual inconsistencies have developed in the usage of "Nebraskan," "Aftonian," and "Kansan" as chronologic, chronostratigraphic, and biostratigraphic units (Boellstorff, 1973a; 1978) in North American sequences, both terrestrial and marine. Because the parceling out of each Pleistocene unit or event to one of the "four" glacials or "three" interglacials clearly is incorrect, these terms are probably best abandoned, at least until extensive studies have clarified the relationships to the type areas.

Third, the correlation of the "Aftonian" fauna of western Iowa to the Afton/Thayer area by Shimek (1910b), Calvin (1910), and Hay (1914; 1925) has been questioned for biostratigraphic reasons (Bar-

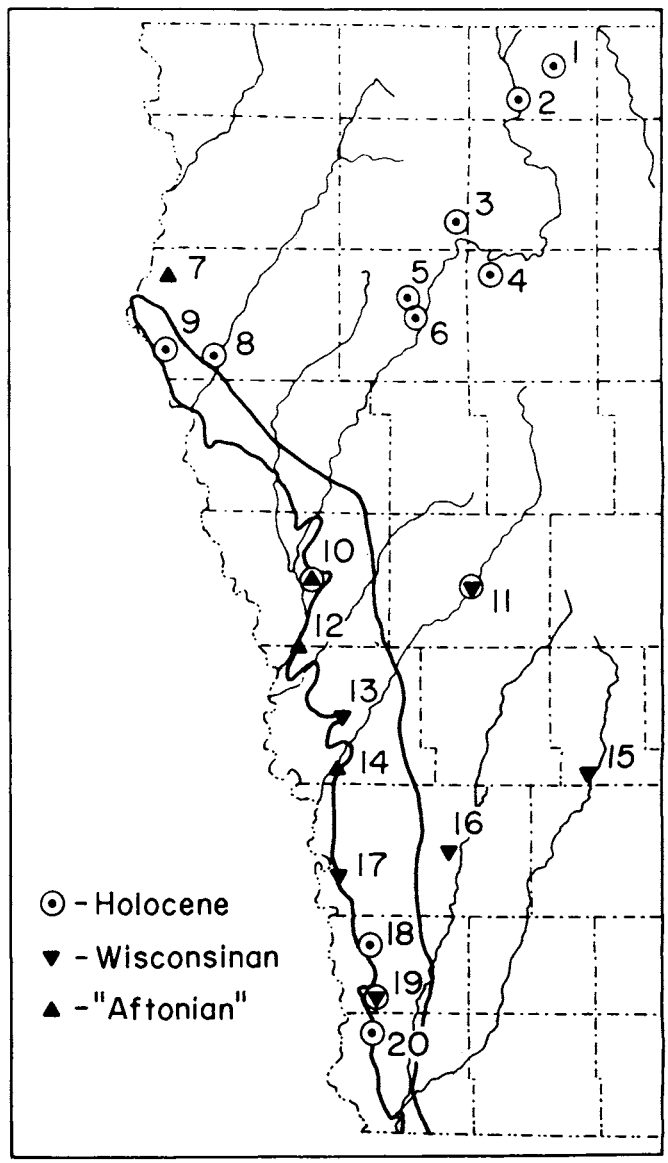


Fig. 1. Map of western Iowa showing the Loess Hills region (outlined; modified from Prior, 1976) and mentioned localities. *Dickinson Co.:* 1) Arthur (13DK27), 2) Milford (13DK1). *O'Brien Co.:* 3) Wittrock (130B4). *Buena Vista Co.:* 4) Chan-ya-ta (13BV1). *Cherokee Co.:* 5) Brewster (13CK15) and Phipps (13CK21), 6) Cherokee Sewer site (13CK405). *Plymouth Co.:* 7) Akron well, 8) Rainbow (13PM91), 9) Broken Kettle West (13PM25). *Monona Co.:* 10) Turin and Elliott pits. *Crawford Co.:* 11) Denison pit and M.A.D. sites (13CF101, 13CF102). *Harrison Co.:* 12) Little Sioux (= County Line), 13) Burkholder-Mether mastodon, 14) Cox pit. *Audubon Co.:* 15) Brayton. *Pottawattamie Co.:* 16) Oakland mammoth, 17) Council Bluffs muskox. *Mills Co.:* 18) Glenwood earthlodges (13ML124, 13ML126, 13ML130, 13ML155), 19) Waubonsie drainage (Craigmile, Waubonsie, Garrett Farm, Pleasant Ridge). *Fremont Co.:* 20) Thurman (=Fremont).

bour and Schultz, 1937; Schultz and Stout, 1948:567; Frankforter, 1957; 1971; Schultz and Hillerud, 1977). As vertebrate paleontologists (subsequent to the early 1900's) described the Tertiary and Quaternary mammalian faunas of North America, they detected a geochronologic ordering and subdivided this biostratigraphic sequence into a series of "provincial land mammal ages" (Wood et al., 1941; Savage, 1951; Evernden et al., 1964; Schultz et al., 1978; Kurtén and Anderson, 1980:3-95). The oldest related to the Quaternary is the Blancan which transgresses the Pliocene/Pleistocene boundary; it is followed by Irvingtonian, Rancholabrean, and the "Recent" (= modern) land mammal ages. Gravel pits in the type area of the lithologic "Aftonian" (Afton/Thayer region, Union Co.) have been disappointingly unfossiliferous (Hay, 1914). Nonetheless, a gravel pit near Thayer (exact location and name not recorded) yielded rare vertebrate remains; all of these were from a small, extinct three-toed horse (Calvin, 1909b:138). We visited (April, 1974) a large, inactive gravel pit (0.3 km southwest of Thayer, in SE, NE, Sec. 22, T72N, R28W, Union Co., Iowa) which may be close to Calvin's locality. Bone fragments were present (including a new cheek-tooth of the three-toed horse) but rare on spoil piles from these "Aftonian?" gravels. Calvin later (1911:210-211) implied that his specimens could be referred to "*Hipparion gratum* Leidy" and Hay (1914:150-151) restated Calvin's (1911) opinion but reassigned the fossils to "*Neohipparion gratum?* Leidy." At the time the "Aftonian" mammalian fauna received its name (circa 1908-9), these small horse fossils from the lithologic type area were thought to be redeposited from older sediments (Calvin, 1909b). By 1911, Calvin regarded the fossils to be contemporaneous with the type "Aftonian" gravels and this three-toed horse thus confirmed the antiquity of the entire fauna, even though the taxon was not (and has not been) found in western Iowa localities which yield the "Aftonian" fauna. Such small horses, regardless of the accuracy of the archaic nomenclature, did not survive past the Blancan land mammal age (Kurtén and Anderson, 1980:283-291). Indeed, brief examination of these specimens prompted both Hibbard (1948) and M.R. Voorhies (pers. comm., 1985) to suggest that they represented a pre-Blancan taxon and to reopen the question of their contemporaneity with the lithotype gravels. Thus both dating of and correlation to the Thayer area is uncertain. None of the well-collected pits in the Loess Hills region have yielded this small horse or any of its contemporary associates (Calvin, 1909a; 1911; Hay, 1914). As demonstrated below, all recovered specimens from them are younger than Blancan and the most parsimonious conclusion is that the bulk of the western Iowa "Aftonian" fauna is either latest Irvingtonian or earliest Rancholabrean. These previously correlated units possibly are not coeval and we suggest that the term "Aftonian" should be suppressed for the mammalian fauna at its classic localities in western Iowa.

The Turin and Cox Pits: Classic "Aftonian" Faunal Localities

Given these uncertainties, what is the "Aftonian" fauna of western Iowa (Fig. 2)? Two classic "Aftonian" faunal localities have particular merit for this evaluation: the Turin (originally known as Elliot) pit, Monona Co. (Fig. 1, 10), and the Cox pit, Harrison Co. (Fig. 1, 14). Both have produced extensive collections from fossil-bearing sediments beneath a diamicton (Shimek, 1910a; Dechert, 1968). Diamicton is a non-genetic term indicating a terrigenous sediment with a wide variety of grain sizes in a muddy matrix. The overlying diamictons at each pit are probably pre-Wisconsinan glacial till but

Fig. 2. A turn of the century collection in the Cabinet of National History of prize "Aftonian" fossils from western Iowa. Most of these specimens remain on deposit in the SUI Paleontology Repository. This unretouched print is from a 5 × 8 inch glass plate (#678) in the Calvin collection (Department of Geology, University of Iowa). It is titled "Pleistocene Fauna, Fossil bones from the Aftonian Gravels, Missouri Valley, Pisgah, Harrison county, Iowa."

neither has been examined with modern sedimentological techniques. Either diamicton could be colluvium instead. The Turin pit is within the town of Turin as was the Elliot pit; Dechert (1968) believed them to be only 0.1 km apart. The long-abandoned Elliot pit probably has been engulfed by the Turin pit (Harold Johnston, pit owner/operator, pers. comm. to Semken, 1968). The Turin pit is sporadically mined at present. Both pits yielded fossils from the same gravel unit. The collections from these two pits were referred to as the Turin local fauna (l.f.) by Frankforter (1971).

The faunal list for the Turin/Elliott pit (Calvin, 1909a; 1911; Shimek, 1910a; 1910b; Hay, 1914), updated with additional specimens by Dechert (1968), Frankforter (1971; n.d.), and McDonald and Anderson (1983), now contains 20 large mammal taxa (indicated by "#" symbol in Table 1). At least 6 small mammal taxa also were found: *Lepus* sp., jackrabbit; *Sylvilagus* sp., rabbit; *Geomys* sp., pocket gopher; *Ondatra* sp., muskrat; *Microtus* sp., meadow vole and its allies; and *Lutra canadensis* (Schreber), river otter (Frankforter, 1971; McDonald and Anderson, 1983). All specimens from the Turin l.f. have been recovered incidental to the commercial operation of the Elliot or Turin pits and neither pit was excavated systematically for vertebrate remains.

Despite the archaic nomenclature employed in many of the published specimen identifications, most of the taxa of the Turin l.f. are species with long Pleistocene ranges - Irvingtonian through Rancholabrean (Kurtén and Anderson, 1980). Indeed, all coexist in the Rancholabrean. Two facts allow tentative assignment of the Turin l.f. to the transition between Irvingtonian and Rancholabrean time which is thought to have happened between 1.0 and 0.5 million years ago (Kurtén and Anderson, 1980; Harington, 1984). First, 25 of Turin's 26 identified mammals are present in but not confined to Rancholabrean deposits elsewhere. The cranium of *Megalonyx jeffersonii* (Desmarest), Jefferson's ground sloth, described by McDonald and Anderson (1983), is the sole species confined to the Rancholabrean (Kurtén and Anderson, 1980). Unfortunately, Irvingtonian *Megalonyx* of the midcontinent are poorly known (M.R. Voorhies, pers. comm., 1986); if *jeffersonii*-sized *Megalonyx* were documented in older sites on the Plains, then the age of the Turin l.f. should be reassessed.

Other North American taxa also are confined to the Rancholabrean and are expected to occur in well-collected megafaunas of this age; one of these, *Bison,* Holarctic buffalo, provides a second argument. The only faunal evidence against Rancholabrean age for the Turin l.f. is the absence of *Bison* in these extensive collections (Frankforter, n.d.). This caused Frankforter (1971; n.d.) to suggest an Irvingtonian age for the fauna. *Bison* immigrated from Eurasia and its appearance defines the base of the Rancholabrean (Savage, 1951; Kurtén and Anderson, 1980; Harington, 1984). South of Beringia, the earliest species is *Bison latifrons* (Harlan), giant bison, which was widespread but with low density (Schultz and Hillerud, 1977; Kurtén and Anderson, 1980). Toward the end of the Rancholabrean (Wisconsinan glacial), fossil *Bison* (specific diagnoses are difficult) are common and, after the terminal Wisconsinan extinction of most other large grazers, it expands to dominate the central North American steppes (Guthrie, 1984). Thus, the apparent conflict of a solely Rancholabrean taxon (*Megalonyx jeffersonii)* occurring in a fauna lacking *Bison* could have been caused by the accumulation of the Turin l.f. at the time of low *Bison* density during the inception of the Rancholabrean. Therefore, the Turin l.f. is best regarded as transitional between Irvingtonian (the preceding land mammal age) and Rancholabrean.

Paleoenvironmental analysis of the Turin l.f. also is hampered by the lack of systematic excavation. Early workers such as Hay (1914) argued that the "Aftonian" fauna, including Turin, must represent an interglacial climate in order to support such a diversity of large mammals. Nearly all the taxa have since been recovered in well-dated contexts associated with glacial climates, in particular the Wisconsinan; the area of active glacial ice of course would have been uninhabitable. Dechert (1968) also examined the faunal lists and determined (by the ratio of inferred browsers to grazers) that the taxa represent an equal mixture open country and forest species. She concludes that this represents a gallery forest with both nearby moist lowland meadows

Table 1
Large mammals known from the Pleistocene of western Iowa

	Taxon	B	I	R	M	[c]
#[a]	*Didelphis* sp.					
#	*[b]*Megalonyx jeffersonii* (Desmarest)					
#	* *Glossotherium harlani* (Owen) (variously "*Mylodon*" or "*Paramylodon*")					
	* *Dasypus bellus* (Simpson)					
#	*Castor canadensis* Kuhl					
#	* *Castoroides ohioensis* Foster					
#	*Canis latrans* Say					
#	*Canis lupus* Linnaeus[d]					
#	*Vulpes* sp.					
#	*Ursus americanus* Pallas					
#	*Procyon* sp.					
#	*Taxidea taxus* (Schreber)					
#	*Panthera* sp.					
#	* *Mammut americanum* (Kerr)					
	* *Stegomastodon mirificus* (Leidy)					
#	* *Mammuthus* sp(p?). (Fragmentary material and nomenclatural difficulties make previous specific diagnoses unreliable)					
#	* *Equus* spp. (as above, but at least 2 taxa probably occur)					[e]
#	* *Platygonus* sp.					
#	* *Camelops* spp. (as with *Mammuthus,* but at least 2 taxa probably occur)					
#	*Odocoileus* sp.					
	*?*Sangamona fugitiva* Hay					
	* *Cervalces scotti* (Lydekker)					
	* *"Alces shimeki"* Hay (archaic binomen, modern assignment unknown)	?	?	?		
#	*Rangifer* sp.					
	Bison sp(p?).					
	* *Symbos cavifrons* (Leidy)					
#	* *"Aftonius calvini"* Hay (probably *Euceratherium collinium* Furlong & Sinclair)					
	Ovibos moschatus (Zimmermann)					

[a] "#" indicates that the taxon was recovered from the Turin l.f. (Turin or Elliot pit): Calvin, 1090a; 1911; Shimek, 1910a; Hay, 1914; Dechert, 1968; Frankforter, 1971; n.d.; McDonald and Anderson, 1983.

[b] "*" indicates an extinct taxon.

[c] Horizontal bar indicates the geochronologic range of each taxon by North American provincial land mammal ages: B = Blancan, I = Irvingtonian, R = Rancholabrean, M = "Recent," ? means that the range is unknown. Geochronologic ranges from Kurtén and Anderson, 1980.

[d] *Canis lupus* includes an undocumented specimen referred to as "dire wolf" by McDonald and Anderson, 1983.

[e] Survived the end of the Pleistocene in the Old World only.

and dry upland prairie. Her inference that the environment was somewhat like that of the present, however, is not supportable because the large mammals which she used (all that were available) have widespread geographic ranges in both supposed glacial and interglacial deposits outside of Iowa.

The Cox pit, Harrison Co. (Fig. 1, 14), near the town of Missouri Valley, also has provided a large collection of fossils; of the western Iowa "Aftonian" localities, it is second only to the Turin pit. Like Turin, the fossil-bearing gravel in the Cox pit is overlain by a so-called "Kansan" till (Shimek, 1910b) but, since the pit has been inactive for many years, this can no longer be verified. The Cox pit has yielded a fauna consisting of 10 taxa, 9 in common with the Turin pit. "*Alces shimeki* Hay," a peculiar but dubious cervid taxon occurs only at the Cox pit (Calvin, 1909a; 1911; Shimek, 1910a; 1910b; Hay, 1914; Dechert, 1968; Frankforter, n.d.). The cited authors have interpreted the Cox pit fauna to represent a similar paleoenvironment to the Turin fauna and consider the two localities to represent the same lithologic unit. In general this is appropriate, but correlation of the fossil-bearing deposits between the two localities will require detailed lithostratigraphic analysis.

A Hint of Antiquity: The Akron *Stegomastodon*

Another of the classic "Aftonian" localities deserves mention, the Akron well, Plymouth Co. (Fig. 1, 7). At this site, a hand-dug well intercepted a sand layer below a pre-Wisconsinan till (Shimek, 1910a). Fragmentary proboscidean remains, including two well preserved molars, of *Stegomastodon mirificus* (Leidy), wonderful stegomastodon, were recovered from the sand (Calvin, 1909a; Shimek, 1910a; Hay, 1914; Osborn, 1924). Although considered part of the "Aftonian" fauna by the cited authors, this locality is distant from the Turin and Cox pits and the correlation is suspect. *Stegomastodon* became extinct in middle Irvingtonian (Kurtén and Anderson, 1980) and the site easily could be substantially older than either the Turin or Cox pits. The Akron well does indicate that early Plesitocene deposits are present, but nearly unknown, in western Iowa.

The Little Sioux (County Line) Locality: A New Perspective on the "Aftonian" Fauna of the Loess Hills

The Little Sioux (County Line) site, Harrison Co. (Fig. 1, 12), could provide information of great value in interpreting the prehistory of Iowa's Loess Hills. It contains a radiometrically dated volcanic ash of the Pearlette Family (0.74 ± 0.04 million years ago; Boellstorff, 1973b; 1974; 1976) with micromammal and mollusc remains both immediately below - Little Sioux l.f., and above - Wright l.f. (Paulson and Miller, 1983). The radiometric date (fission-track on glass shards) indicates that these two local faunas are either earliest Rancholabrean or latest Irvingtonian in age. The lithostratigraphy of this site again is poorly understood. The fossil-bearing sediments are sand and silt but the underlying gravel seems unfossiliferous. Shimek (1910a; 1910b), a generally acute observer, considered these stratified deposits to be "Aftonian," but he did not recognize that his "whitish silt" included a volcanic ash. He also recorded 12 feet of "Kansan" till above the "Aftonian" sediments; this overlying diamicton has not been mentioned since. Kay and Graham (1943:85-88) recognized the ash but described only the 6 feet of section including it. They attributed this part of the section to the "Loveland" interval. Frye et al. (1948:504-505) and Condra and Reed (1950:23-24) both present hypothetical interpretations of this site, unsupported by measured sections, but neither includes an overlying till. Boellstorff (1973a) described a single detailed secton but again an overlying till is not described. The relationship of this ash deposit and its associated faunas to these pre-Wisconsinan glacial and non-glacial sediments must be reassessed by a detailed lithostratigraphic analysis of this site before regional correlations can be made.

Paulson was the first to collect mammal fossils from the Little Sioux locality. Unfortunately neither local fauna is fully analyzed but each of them (Little Sioux and Wright l.f.) contains both mammals and molluscs representing cooler and more moist conditions than today (Paulson and Miller, 1983). The Little Sioux represents more moist and cooler conditions than the Wright l.f. and also has at least two extinct species of small mammals (Paulson and Miller, 1983).

The "Aftonian" Fauna: Summary

All of the above faunas (except the Akron *Stegomastodon* and the Thayer horses) are too late in time to be early Pleistocene. Only 10 of the 21 "Aftonian" large mammal taxa are known from the Blancan, and it seems likely that this list could be reduced with accurate diagnosis of the specimens to species. Conversely all are known to occur in Wisconsinan age sediments. Thus the type "Aftonian" fauna of western Iowa (*not* the lithologic type) can not be "Aftonian" in the generally understood, early Pleistocene sense. These localities are (except Akron) late middle Pleistocene at the earliest and could be much younger.

PROCEDURES, CAVEATS, AND CONVENTIONS IN FAUNAL ANALYSIS OF WISCONSINAN AND HOLOCENE SITES

Site Selection

This paper presents a literature summary of all significant Wisconsinan and Holocene vertebrate sites known to us from the Loess Hills Region and nearby areas of western Iowa. To be considered, each site had to yield 10 or more distinct mammalian taxa. This criterion eliminated many zooarcheological and paleontological sites where only megamammals (*Bison; Mammuthus,* mammoth; etc.) have been recovered. Almost all of the sites meeting this criterion have been bulk-sampled and waterscreened on window screen ($1/16''$ opening; about 1.6 mm) or finer mesh wire-cloth for recovery of microvertebrates (rodents, etc.). Indeed, both bulk-sampling and waterscreening are required procedures to ensure reliability in paleoenvironmental analysis. All 6 discussed non-cultural local faunas have been collected in this fashion and 6 of the 11 discussed archeological sites (11 of 17 analyzed faunules) are known to have been as well.

Dating the Faunas

Fortunately, most Wisconsinan and Holocene sites are suitable for radiocarbon age-dating techniques because most contain charcoal or other datable material. All known radiocarbon dates from Iowa archeological sites (as of August, 1979) have been tabulated by Tiffany (1981). All radiometric dates in this paper are reported in "radiocarbon years before present." None of these dates have been "corrected" for the effect of secular variation in ^{14}C. The designation "RCYBP" is used for actual dates, and "present" conventionally means the year AD 1950. Inferred, rounded, or averaged dates are indicated by "YBP;" these also are reported in uncorrected radiocarbon years before present.

Special reservations are acknowledged concerning the radiocarbon dating of late Holocene sites. Two factors cause greater potential for misinterpretation of young dates even though they are of equal or greater precision to those from older contexts. First, the longevity of many tree species is great. Charcoal derived from the heartwood in logs of documented western Iowa trees could be as much as 400 years older than the sapwood: *Juniperus virginiana* Linnaeus, eastern red cedar, 369 years old (Anderson, 1938); *Quercus macrocarpa* Michaux, bur oak, 400 years old (R.Q. Landers cited in Duvick and Blasing, 1983). Moreover, heartwood has a greater probability of carbonization than sapwood because it is protected from the oxygen needed for complete combustion by the sheathing sapwood (D.C. Anderson, pers. comm., 1984). Even in rapidly growing species this differential could amount to as much as 50-150 years and thus cause an erroneously old date to be attributed to a depositional or cultural unit (Hotopp, 1978a:207; Anderson, 1985). Second, semi-sedentary ag-

riculturalists in western Iowa constructed permanent habitations using large timbers for support. Undoubtedly, these timbers were repeatedly salvaged so long as they were in serviceable condition (Hotopp, 1978a:188 and 207). Thus the first effect is compounded (Anderson, 1985). Both of these factors are critical in the more finely divided chronology of the late Holocene because their magnitude is potentially a significant fraction of the age of the sites being dated.

Only two of the western Iowa archeological sites have not been dated by the radiocarbon method (Arthur site, Tiffany, 1982a:192; Milford site, Spargo, n.d.). We have assigned ages to these two local faunas by the typology reported for the majority of the material artifacts found associated with the faunal remains. Correlation by seriation of material artifacts (in the absence of radiocarbon dates) is useful when the seriational sequence is well anchored in time by radiocarbon dating elsewhere and it can serve as a sensitive discriminator either within multicomponent sites or between sites where radiocarbon chronology is uncertain (Semken, 1983).

Chronology and Climatic Episodes

North American paleoclimatologists and archeologists have divided the Holocene into ten "climatic episodes" (Wendland and Bryson, 1974; Wendland, 1978), the names of which were modified from the Blytt-Sernander schema for northwestern Europe (see Mangerud et al., 1974). Global significance and synchroneity of episode boundaries also was suggested by Wendland and Bryson (1974). If the boundaries between these episodes are synchronous, the nomenclature is justified. The evidence is suggestive but in many areas the synchroneity is far from proven. Indeed, the lack of good correlation of some episode boundaries to lithostratigraphic units in the De Forest Fm. alluvial sequence in the Loess Hills (Bettis and Thompson, 1981; 1982a) casts doubt on the regional significance of some of these episodes. The senior author believes that the episode names were an unfortunate nomenclatural choice because such an intercontinental terminology encourages the forcing of results into rigid "pigeonholes" while obscuring potentially significant regional disparities. He prefers a purely local geochronological nomenclature. Nonetheless, the entrenched and customary usage of these terms in the archeological and paleoclimatological literature necessitates their usage below.

Analysis of the Faunal Remains

Quaternary paleoecological analysis is based on analogy to the modern biota and environment. Unfortunately, urbanization and agricultural exploitation has left little, if any, of the Loess Hills untouched (Farrar et al., 1985). Although the present-day mammalian fauna has been described (Lampe and Bowles, 1985), little information is available on presettlement distributions other than infrequent museum records (Bowles, 1975). Most mammals depend on the structure and composition of the vegetation for cover and sustenance. Although better known than the fauna, the presettlement vegetation of the Loess Hills also is poorly recorded (Shimek, 1910b:426-483; Shimek, 1911; Kildee, 1935:18, Fig. 16). Novacek et al. (1985) describe the modern flora and discuss the probable natural vegetation of the Loess Hills region. Because of both this uncertainty about the nature of the local presettlement biota and the occurrence as fossils of taxa now living in distant regions, it is necessary to consider less detailed, but broader scope, studies (Shelford, 1963; Hoffmann and Jones, 1970; Hall, 1981). Three methods have been used to analyze and compare the faunas from each site.

Analysis of areas of sympatry — The modern geographic distributions of the identified fossil species recovered from a site or horizon are plotted on a single base map. The area in which all species co-occur or overlap (or at least the greatest number) is called the "area of sympatry" for the local fauna. A number of factors can detract from the precision of this analysis. (1) The accuracy of taxonomic diagnoses is the most difficult to control in a literature summary. (2) Remains from multiple lithostratigraphic or cultural units occasionally are combined to insure adequate sample size. Thus taxa are treated as contemporaneous when in reality they are diachronic. (3) In fluvial sedimentary environments (all of our non-cultural localities), taphonomic studies show that bones and teeth behave like hydrodynamically equivalent, non-fossil clasts (Voorhies, 1969; Wolff, 1973; Korth, 1979). Thus, mega- and micromammals rarely are preserved together in the same depositional environments. (4) Furthermore, because of their substantially smaller initial populations, carnivores are less likely to be recovered than herbivores; and bats, because of their preferred habitats and life style, also are rare fossils (except in caves). (5) Even where depositional biases are minimal, excavation procedures (e.g. lack of waterscreening) bias faunal samples.

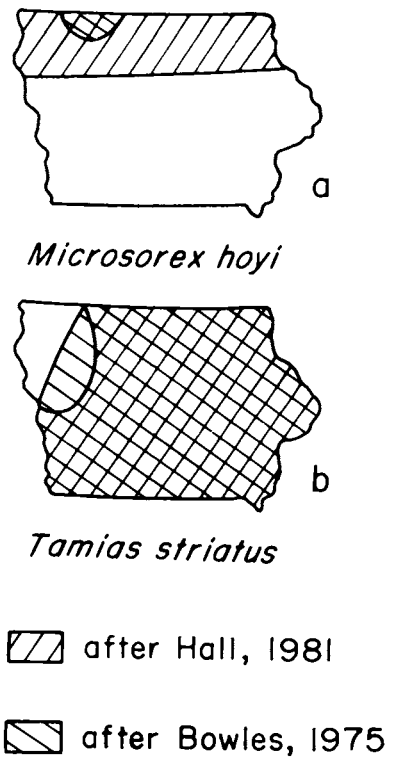


Fig. 3. Present geographic range (hachured) in Iowa of two mammals: a = *Microsorex hoyi*, b = *Tamias striatus*. Interpretations by Hall (1981) and Bowles (1975) for each species.

To insure the greatest compatibility between disparate analyses, our sympatries have been constructed using only Insectivora (shrews and moles), Lagomorpha (rabbits and hares), and Rodentia (rodents). These are termed "ILR" taxa herein and are tabulated for each site in Table 2. The large rodents *Castor canadensis* Kuhl, beaver, and *Erethizon dorsatum* (Linnaeus), porcupine, could be considered "large" mammals and probably are underrepresented in non-cultural micromammal accumulations. Three rodent taxa are considered to be commensals associated with human habitation and are excluded from the analysis of the areas of sympatry. Two, *Mus musculus* Linnaeus, house mouse, and *Rattus norvegicus* (Berkenhout), Norway rat, were introduced by European immigrants to Iowa. The third, *Oryzomys palustris* (Harlan), marsh rice rat, is a North American native but probably was a commensal pest to the north of its modern range in some Native American communities well before the time of European conquest (Goslin, 1951; Guilday, 1955; Bardwell, 1981). The modern ranges of all remaining non-ILR taxa (except for domesticates) were examined for occurrence in the resulting area of sympatry and

Table 2
Occurrence of Insectivora, Lagomorpha, and Rodentia ("ILR" taxa) in Wisconsinan and Holocene local faunas and faunules from western Iowa.

					Cherokee Sewer site faunules					Rainbow site faunules										Glenwood locality earthlodge faunules				
	Center of distribution[a]	Craigmile l.f.	Waubonsie l.f.	Brayton l.f.	Cultural Horizon III	Cultural Horizon II	Cultural Horizon I	Garrett Farm l.f.	M.A.D. site, Boyer varient faunules	Cultural Horizon A	Cultural Horizon C	Pleasant Ridge l.f.	Arthur l.f.	Broken Kettle West l.f. House 3 faunule	Chan-ya-ta l.f. Feature 6 faunule	Brewster l.f.	Phipps l.f.	Wittrock l.f.	Thurman l.f.	13ML126 Hilltop - 852 YBP	13ML155 Hilltop - 698 YBP	13ML130 Terrace - 807 YBP	13ML124 Terrace - 735 YBP	Milford l.f.
INSECTIVORA																								
Sorex																								
S. arcticus	B	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. cinereus	B	X	X	X	X	X	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
S. palustris	B	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Microsorex hoyi	B	X	-	-	-	-	Xn	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Blarina																								
B. brevicauda undet.	D[b]								X							X	X							X
B. b. brevicauda	D[b]	X[f]	-	-	X[f]	X[f]	X[f]	-	-	-	-	X[f]	+	-	-	-	-	-	X[f]	-	-	X	X	-
B. b. talpoides (= "B. b. kirtlandi")	D[b]	-	X[f]	-	-	-	-	X[f]	-	-	-	-	-	-	-	-	-	-	X?[f]	-	-	X?	-	-
B. hylophaga (= "B. carolinensis")	D[b]	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cryptotis parva	D	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	X	-	-	-	X	-	-	-
Scalopus aquaticus	D	X	X	-	-	X	-	X	X	-	-	X	-	+	-	-	X	-	X	X	X	X	-	X
LAGOMORPHA																								
Leporidae undetermined	-	X	X	X	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
Sylvilagus sp(p).	I	-	-	-	-	X	-	-	X	X	X	-	+	+	+	X	X	+	X	X	X	X	X	-
Lepus sp(p).	I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-	-	-
RODENTIA																								
Tamias striatus	D	X	X	-	X	-	-	-	X	-	-	-	+	-	-	-	X	-	X	-	X	-	X	-
Eutamias minimus	B	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marmota monax	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
Spermophilus																								
S. franklinii	S	X	X	-	-	-	X	-	-	X	X	X	-	-	+	X	X	+	-	X	X	X	X	X
S. tridecemlineatus	S	X	X	X	-	-	-	X	-	-	X	X	-	+	+	X	X	+	-	X	X	-	X	X
Cynomys ludovicianus	S	O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sciurus undetermined	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	X	-	-	-	-	-
S. niger	D	-	-	-	-	-	-	-	-	X	X	-	-	-	+?	-	-	-	-	-	X	-	X	-
Tamiasciurus hudsonicus	B	-	X	X	-	X_e	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Thomomys talpoides	B	O	O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Geomys bursarius	S	X	X	X	X	X	X	X	X	X	X	X	+	+	+	X	X	+	X	X	X	X	X	X
Perognathus																								
P. flavescens	S	-	-	-	-	-	-	X	-	-	-	X	-	+?	-	-	-	-	-	X	X	-	X	-
P. hispidus	S	-	-	-	-	X_w	X_s	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Castor canadensis	W	-	-	-	X	-	-	-	X	X	X	-	+	+	+	X	X	+	-	-	X	X	X	X
Oryzomys palustris	-[c]	-	-	-	-	-	-	-	C	-	-	-	-	-	-	-	-	-	-	C	C	C	C	-

Reithrodontomys																								
R. megalotis	S[d]	-	-	-	X	X	-	-	-	-	-	-	+?	-	-	-	-	-	-	-	-	-	-	-
Peromyscus undetermined	-	X	X	-	-	-	-	-	X	-	-	-	-	+	-	X	X	-	X	-	-	-	-	-
P. leucopus	D	-	-	-	X	X	X	X	-	X	X	X	-	-	-	-	-	-	-	X	X	X	X	-
P. maniculatus	W	-	-	-	X	X	-	X	-	-	-	X	-	-	-	-	-	-	-	X	X	X	X	X
Onychomys undetermined	-	-	Xw	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O. leucogaster	S[d]	-	-	-	-	-	X	X	-	-	-	X	-	-	-	-	-	-	-	X	X	-	-	-
Neotoma undetermined	-	-	O	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
N. floridana	D	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
Clethrionomys gapperi	B	X	X	X	-	-	-	O	-	-	-	-	+	-	-	-	-	-	-	-	-	-	X	X
Phenacomys intermedius	B	O	O	O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Microtus																								
M. (Pedomys) ochrogaster	S	X	X	-	X	X	X	X	X	X	X	X	-	-	-	-	X?	-	X	X	X	-	X	X
M. pennsylvanicus	B	X	X	X	X	X	X	X	X	-	-	X	+	-	-	-	-	-	X	-	X	-	-	X
M. (Pitymys) pinetorum	D	X	Xe	X	-	-	-	-	-	-	-	X	+	-	-	-	-	-	-	-	-	-	X	-
M. xanthognathus	B[e]	-	O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ondatra zibethicus	W	X	-	-	-	-	-	-	-	X	-	X	+	+	+	X	X	+	-	X	X	X	X	X
Synaptomys																								
S. borealis	B[e]	O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. cooperi	B	X	X	X	-	X	-	X	X	-	X	X	-	-	-	-	-	-	X	X	-	X	X	-
Rattus norvegicus	-[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C
Zapus undetermined	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z. hudsonius	B	-	X	-	X	X	-	X	-	-	-	X	+	-	-	-	-	-	-	-	-	-	-	X
Erethizon dorsatum	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Number of ILR taxa		24	22	10	11	14	10	17	11	8	9	19	10	9	7	10	15	6	12	13	17	12	17	15
MNI of ILR taxa (excluding commensals)		166	117	14	16	49	17	58	27	26	165	62	30	44[g]	12	461	515	23	29	26	40	25	30	70
MNI of commensals		-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	21	27	21	5	2

[a] Center of distribution (B = boreomontane, S = steppe, D = deciduous forest, W = widespread) after Hoffmann and Jones (1970) except as noted.

[b] Hoffmann and Jones (1970) recognize only one species — all phena are herein considered to have a center of distribution in the "deciduous forest" (= eastern North America).

[c] Not assigned to a center of distribution by Hoffmann and Jones (1970) — considered herein to be a commensal pest around human habitations.

[d] Center of distribution is given as "southwestern" by Hoffmann and Jones (1970) — here considered as "steppe."

[e] Center of distribution not assigned by Hoffmann and Jones (1970) — here considered as "boreomontane."

[f] Identifications of these *Blarina* specimens have been verified by Jones et al., 1984.

[g] These MNI's were calculated by Alex (1970) on a per feature basis and this number probably is greater than would be produced by our standard methods. Absence of raw data in the cited source prevents recalculation.

KEY TO SYMBOLS:

- = Taxon not identified in sample.
+ = Present in sample but no sympatry illustrated.
C = Commensal taxon, cannot be determined if would occur in a sympatry.
? = Identification uncertain.
X = Present in sample and found in the area of sympatry.
Xn = north, Xs = south, Xe = east, Xw = west — if a fauna has more than one area of sympatry and the taxon is not present in both, then the lower case letter indicates in which sympatry taxon is present.
O = Present in sample but does not occur in any maximal area of sympatry.

any disparities are described for each site. Non-ILR taxa are tabulated in Table 3.

The source of modern distributional data also influences the area of sympatry. Distributions presented in regional studies (e.g. Iowa - Bowles, 1975; North and South Dakota and Nebraska - Jones et al., 1983) frequently do not match where adjacent, and rarely correspond precisely to those mapped for North America (Hall, 1981). Substantial differences are seen in some interpreted distributions. *Microsorex hoyi* (Baird), pigmy shrew (Fig. 3a) is believed to be distributed throughout 30 northern Iowa counties by Hall (1981:52, Map 31). Bowles (1975:33, Fig. 5) mapped it in only 7 counties. Both interpretations are based on the same 2 specimens from a single Iowa collecting station. *Tamias striatus* (Linnaeus), eastern chipmunk (Fig. 3b) represents another discrepancy. Hall (1981:339, Map 234) based his range in Iowa on Bowles' map, Fig. 20 (1975:62). Unfortunately, the range maps for *T. striatus* and *Sciurus carolinensis* Gmelin, grey squirrel (Bowles, 1975:70, Fig. 24) were inadvertently transposed in Bowles and this error carried through into Hall (1981). Fortunately, Bowles presents both locality dots and a textual locality register so the transposition can be detected.

European settlement and modern changes in land use practices may have had a nearly undetectable impact on small mammal ranges as

Table 3
Occurence of Chiroptera, Edentata, Carnivora, Proboscidea, Perissodactyla, and Artiodactyla ("non-ILR" taxa) in Wisconsnan and Holocene local faunas and faunules from western Iowa.

				Cherokee Sewer site faunules					Rainbow site faunules											Glenwood locality earthlodge faunules				
	Craigmile l.f.	Wauboncsie l.f.	Brayton l.f.	Cultural Horizon III	Cultural Horizon II	Cultural Horizon I	Garrett Farm l.f.	M.A.D. site, Boyer varient faunules	Cultural Horizon A	Cultural Horizon C	Pleasant Ridge l.f.	Arthur l.f.	Broken Kettle West l.f. House 3 faunule	Chan-ya-ta l.f. Feature 6 faunule	Brewster l.f.	Phipps l.f.	Wittrock l.f.[e]	Thurman l.f.	13ML126 Hilltop - 852 YBP	13ML155 Hilltop - 698 YBP[g]	13ML130 Terrace - 807 YBP[g]	13ML124 Terrace - 735 YBP	Milford l.f.[h]
CHIROPTERA																								
Chiroptera undetermined	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	
Eptesicus fuscus	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Lasiurus cinereus	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
EDENTATA																								
*Dasypus bellus	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	
CARNIVORA																								
Canis undetermined	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	D?			D?	-	
C. familiaris	-	-	-	-	-	D	-	D?	D?	D?	-	D?	-	D?	D?	D?	-	-	-			-	D?	
C. latrans	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X	X	+	-	-			-	-	
C. lupus	-	-	-	-	-	-	-	-	-	-	-	-	+	-	X	X	+?	-	-			-	-	
Vulpes																								
V. velox	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-			-	-	
V. vulpes	-	-	-	-	-	-	-	-	X	X	-	-	+	-	X	X	-	-	-			-	-	
Urocyon cinereoargenteus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-			-	-	
Ursus americanus	-	-	-	-	-	-	-	-	X	-	-	-	-	-	X	-	-	-	-			-	-	
Procyon lotor	-	-	-	-	-	-	-	X	X	X	X	+	-	+	X	X	-	-	-			-	X	
Martes americana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-			-	-	
Mustela undetermined	X	-	-	-	-	-	X?	-	-	-	-	-	-	-	-	-	-	-	-			-	-	
M. vison	-	-	-	-	-	-	-	-	X	X	X	+	-	+?	X	X	+	-	-			-	X	
Taxidea taxus	-	-	-	-	-	-	-	-	X	X	-	-	-	-	X	X	-	-	-			-	-	
Mephitis undetermined	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	
M. mephitis	-	-	-	-	X	-	-	-	-	X	-	-	-	+	X	X	+	-	-			-	X	
Lutra canadensis	-	-	-	-	-	-	-	-	-	X	-	+	-	+	X	X	+	-	-			-	X	
Lynx undetermined	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-			-	-	
L. rufus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X			-	-	
PROBOSCIDEA																								
*Mammut sp.	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	
*Mammuthus sp.	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	
PERISSODACTYLA																								
*Equus sp.[a]	*	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	
ARTIODACTYLA																								
Artiodactyla undetermined	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	
Cervidae undetermined	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-			-	-	

Cervus elaphus	-	-	-	-	-	X	X	X	-	X	-	+	+	+	X	X	+[f]	-	X			-	X
Odocoileus sp.[b]	-	-	-	X	-	-	-	X	X	X	-	+	+	+	X	X	+	X	X			X	X
*Sangamona fugitiva	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-
*Cervalces scotti	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-
Rangifer sp.	-	-	O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-
Antilocapra americana	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-			-	-
Bison undetermined	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-
B. bison	-	-	-	X	X	X	X	X	X	X	X	+	+	+	X	X	+	X	X			X	X
*Symbos cavifrons	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-
Number of non-ILR taxa	7	1	6	2	4	4	4	5	8	11	5	8	6	8	13	15	8	2	5	--[g]	--[g]	3	8
MNI[c] of non-ILR taxa (excluding domesticates)	7	1	6	12	18	14	4	25	11	18	5	16	46[d]	42	170	203	--[e]	2	5	--	--	3	47
MNI[c] of domesticates	-	-	-	-	-	2	-	3	1	2	-	2	-	5	16	20	--[e]	-	1	--	--	1	9

[a] Native North American *Equus* became extinct at the end of the Pleistocene; the Eurasian variety was reintroduced by European immigrants.

[b] *Odocoileus* from western Iowa is almost invariably diagnosed as *O. virginianus*, however, it is difficult to morphometrically separate this taxon from *O. hemionus* which probably also lived in the Loess Hills in presettlement time. In the absence of definitively identified specimens, we have recorded all specimens of this genus of deer as only *Odocoileus*.

[c] In most cases the MNI's of the large mammals were calculated using all identifiable elements, either cranial or post-cranial, and thus are somewhat incompatible with the MNI's of the ILR taxa.

[d] These MNI's were calculated by Alex (1970) and Staab (1970) on a per feature basis and this number probably is greater than would be produced by our standard methods. Absence of raw data in the cited sources prevents recalculation.

[e] Semken (1971) includes only incidental large mammal specimens and excavation MNI's are not representative of actual frequencies of occurrence.

[f] Occurrence reported in Frankforter (1969) and not by Semken (1971).

[g] Large mammals have not been studied.

[h] Preliminary study in manuscript (Spargo, 1985) on file with the specimens in the Paleontological Repository, Department of Geology, University of Iowa.

KEY TO SYMBOLS:

- = Taxon not identified in sample.
+ = Present in sample but no sympatry illustrated.
D = Domesticated taxon, present in sample but inappropriate for analysis of sympatry.
? = Identification uncertain.
X = Present in sample and found in the area of sympatry.
O = Present in sample but does not occur in the maximal area of sympatry.
* = Extinct taxon, present in sample but occurrence in area of sympatry is indeterminable.

well (Semken, 1983). For example, Bowles (1975) believes *Lepus townsendii* Bachman, white-tailed jack rabbit, expanded its range significantly with settlement. Furthermore, Lampe et al. (1981) suggest that, because of changing land use patterns, *Spermophilus richardsonii* (Sabine), Richardson's ground squirrel, may still be expanding its range.

The selection of the set of modern distribution maps to be used for plotting areas of sympatry therefore is of critical importance. If different sources are used to generate an area of sympatry for the same faunal list, each may cause it to plot in different locations and may even influence the number of taxa present in it. For internal consistency and maximum reproducibility we have replotted all published areas of sympatry. Jones et al. (1984) is used for *Blarina*, short-tailed shrew; Hall (1981) for all other taxa. Figure 4 demonstrates the potential effect on one faunule: Glenwood earthlodge 13ML155. The difference between the location of the area sympatry of Bardwell (1981), based on composite maps prepared from Burt and Grossenheider (1976) and Bowles (1975), and ours is clear and certainly influences faunal analysis. Where strict adherence to Hall (1981) has led to serious conflict with Bowles (1975), we have explained.

Interpretation of an area of faunal sympatry is based on the assumption that the paleoclimate at the site of the local fauna (and at the time of deposition) will be like that where the modern ranges overlap. Where all taxa, which occur together as fossils, can be found in one area today (a "harmonious" assemblage) this probably is a valid assumption. When one or more taxa do not live in the area of sympatry (a "disharmonious" assemblage), then there probably is not an exact modern climatic analog for the local fauna. Most Wisconsinan-age local faunas are strongly disharmonious, and this suggests that glacial paleoclimates lack a modern counterpart.

Analysis of relative frequencies — The relative frequencies at which species occur in a fossil-bearing horizon is also a valuable analytical tool. Frequencies have been calculated in two ways herein, one based on the number of taxa representative of a distributional center, the other on the number of individuals which can be assigned to each center. The ILR taxa have been assigned to their respective modern center of distribution (Table 2) after Hoffmann and Jones (1970). Omitting indeterminate taxa and commensals from the sum, the relative percentage of taxa with boreomontane, steppe, deciduous forest, southern, and widespread centers of distribution (Table 4) was calculated. In the second method, the taxa were weighted by the respective minimum number of individuals ("MNI") for each in the sample. This generally represents a count of the most frequently occurring dental element of each taxon in an excavation unit. The relative frequencies were then calculated for the same centers of

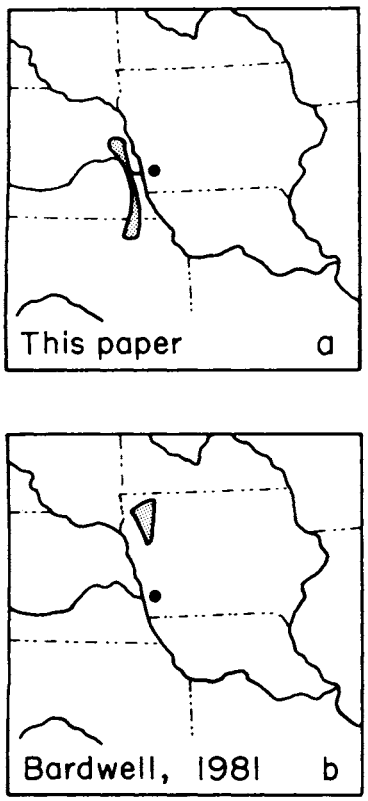


Fig. 4. Area of mammalian sympatry for the Glenwood earthlodge 13ML155 faunule: a = this paper, b = Bardwell, 1981. Each was constructed using the same faunal list but different biogeographic sources.

distribution using the sum of the MNI's for all ILR taxa. Since taphonomically similar, modern control samples are not available, the MNI-based percentages can not be directly compared to modern mammalian faunas, but they can be used to compare the fossil samples with each other.

Analysis of habitat preferences — The modern habits and habitats of the recovered fossil taxa also are useful for paleoenvironmental analysis, both qualitatively and quantitatively (MNI percentages). For example, although having a "boreal" center of distribution (Hoffmann and Jones, 1970), *Microtus pennsylvanicus* (Ord), meadow vole, is an inhabitant of moist meadows with dense grass cover. It is thus an open-ground indicator (at least small forest glades are needed) and it ranges across both forest and steppe far to the south of the boreal forest in any suitable temperate, grassy microhabitat (Reich, 1981).

The "Cultural Filter"

Seventeen of the 20 Holocene faunules and local faunas are recovered from cultural contexts and maybe variously effected by a "cultural filter" (Semken, 1983; Semken and Falk, in press). These distortions could be caused by subsistence procurement, human modification of the local environment, trading practices, and a myriad of other cultural factors. These activities cause different taphonomic biases than those in non-cultural sites (Grayson, 1981). Close observation during the careful excavation and detailed analysis of any archeological or non-cultural site should reveal site-specific characteristics that allow compensation for taphonomic biases, expose limitations of faunal analysis, and facilitate inter-site comparisons. Any analytical difficulties caused by taphonomic biases are noted as encountered below.

THE TALES OF TWO SIZES: MEGA- AND MICROMAMMALS OF THE WISCONSINAN FAUNA

The Wisconsinan is the most recent glacial stage, and contrary to the assertions in Harington (1984) and Jones et al. (1984) the Wisconsinan marks the closing phase of the Rancholabrean land mammal age as defined by Savage (1951:289). Since the "Recent" land mammal age is defined as that part of geologic time with a modern or near modern faunal composition, the impoverished (essentially modern) post-glacial local faunas of Holocene time are excluded from the Rancholabrean.

Even though thick Wisconsinan loess covers most of western Iowa, it has directly yielded few fossil vertebrates because its upland depositional environment is generally unfavorable for bone preservation. However, fossils commonly are derived from alluvial deposits associated with the loess. The list of large mammals in Table 1 includes all taxa reported from Wisconsinan-age deposits. Most specimens are isolated finds, often on gravel bars in modern streams (e.g. Delavan, 1926), and their actual age is uncertain. However, each taxon (except for the Irvingtonian *Stegomastodon mirificus*) has been found buried in a North American locality of undoubted Wisconsinan age.

Isolated Finds

The most frequently reported isolated fossils are those of the proboscidean taxa *Mammuthus* spp. and *Mammut americanum* (Kerr), American mastodon. These figure prominently in the lists of both Hay (1914) and Clement (1932). Indeed, Anderson (1905) and Anderson and Williams (1974) have compiled locality registers devoted solely to proboscideans. Assuming that most of the specimens in Anderson and Williams (1974) list of western Iowa proboscideans are Wisconsinan, the 2.7/1 ratio (71 to 26 localities) of *Mammuthus* spp., a grazer, to *M. americanum*, a browser, suggests that grasslands were more prevalent than forested areas during Wisconsinan time. This conclusion is supported by the composite megafaunal list (Table 1) in that, among the herbivores, grazing taxa outnumber the browsing taxa.

A few specimens have been reported from more certain contexts. McGee (1887) reported a fragmentary skeleton of *Symbos cavifrons* (Leidy), bonnet-horned muskox, from the loess at Council Bluffs, Pottawattamie Co. (Fig. 1, 17). Hay (1914:305-306) and Clement (1932) ultimately described these remains. Hay (1914) questioned the stratigraphic association with the loess but McGee (1887) gave a precise height of the excavation above the river valley that is consistent with recovery from the Wisconsinan loess. Since the loess along the Missouri Valley is clearly Wisconsinan in age (Ruhe, 1969:37-42) and *Symbos* did not elsewhere survive the end of the Wisconsinan (Mead and Meltzer, 1984), the assignment of this individual to Wisconsinan age seems well justified.

The Wisconsinan presence of *M. americanum* is confirmed by its occurrence (post-cranials only) in the Burkholder-Mether site (Fig. 1, 13) along the Willow River in Harrison Co. (Anderson and Williams, 1974). Spruce wood associated with this individual was dated at 13,520 ± 135 RCYBP (WIS-712; Bender et al., 1976). Davis et al. (1972) reported the excavation of an individual of *Mammuthus ?jeffersonii* (Osborn), Jefferson's mammoth, from the base of the Wisconsinan loess near Oakland, Pottawattamie Co. (Fig. 1, 16). Fragmentary remains of 4 other taxa (4 MNI) were also unearthed: an unidentified lagomorph; *Phenacomys intermedius* Merriam, heather vole; *M. pennsylvanicus*; and *Vulpes vulpes* (Linnaeus), red fox (Davis et al., 1972).

The occurrence of *Homo sapiens* Linnaeus, modern human, in Wisconsinan loess above the Turin pit, Monona Co. (13MN2; Fig. 1, 10), initially was reported by Krieger (1956) and later by Wormington (1957:246-248). These bones ultimately were radiocarbon dated at 4,720 ± 250 RCYBP (M-932, whole bone; Crane and Griffin,

1961). A nearby *Bison* skeleton, 8 feet below the human remains, also was dated (6,080 ± 300, M-1071, whole bone; Crane and Griffin, 1961). These concordant dates are Holocene, not Wisconsinan, in age (McKusick, 1964:68-72). This site has been completely reviewed (Fisher et al., 1985) and the human remains represent 4 discrete aboriginal internments in a gully which was later filled by loess-derived alluvium or slump. The similarity of redeposited to undisturbed loess as demonstrated by this spurious Wisconsinan association indicates the need for accurate and detailed observation of the local lithostratigraphy when working in the Loess Hills Region. Both the primary eolian loess of the upland divides and loess-derived colluvium and alluvium are easily reworked particularly near the steep gradients of the bluff line. The nearly uniform lithology of these thick deposits provides only a small variety of clast types to the alluvial systems. Cyclic erosion and redeposition of these sediments within small areas can therefore result in deposits of greatly different age but with very similar appearance. Mass movement, such as slumping, in these nearly homogeneous materials is also very difficult to detect.

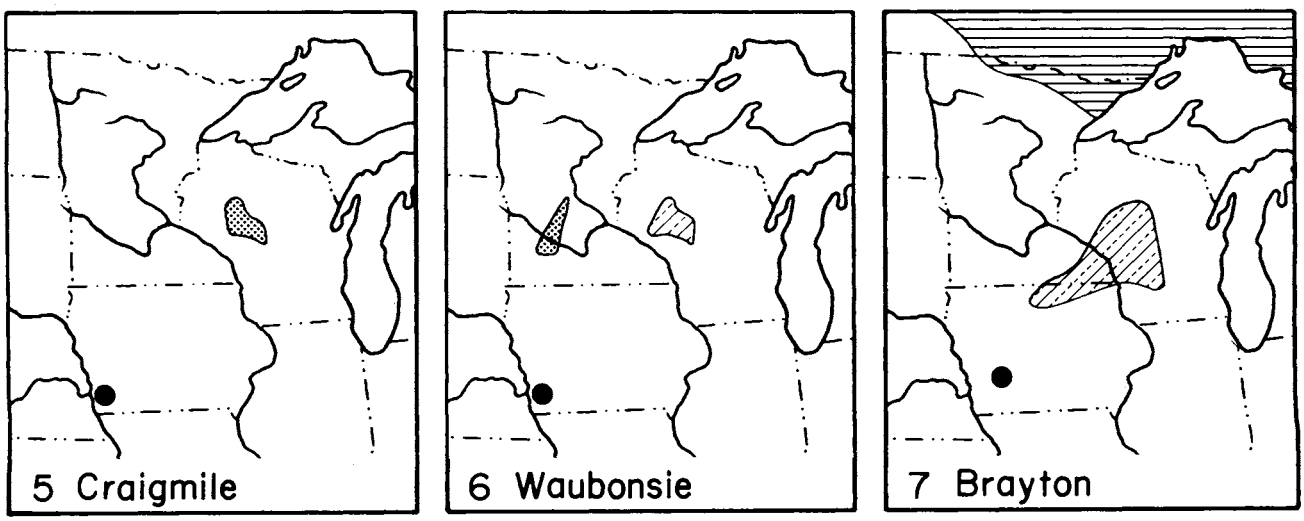
Wisconsinan Local Faunas

Three interpretable Wisconsinan local faunas (10 or more taxa), the Craigmile, Waubonsie, and Brayton, have been reported from western Iowa (Dulian, 1975; Rhodes, 1984). All are radiocarbon dated, systematically bulk-sampled, and waterscreened on 1.6 mm screen. They therefore support more detailed paleoenvironmental inferences than isolated specimens or those collected incidental to the operation of commercial aggregate quarries. None of the recovered micrommals are extinct, but all three local faunas contain small mammals which now live only well to the north or northwest of Iowa. These climatically extirpated species are generally adapted to more boreal climates than those in western Iowa today. The other recovered species are present-day residents of the area. From both the faunal lists (Tables 2 and 3) and areas of sympatry (Figs. 5, 6, and 7), the disharmonious associations are evident. The Wisconsinan biotas therefore represent unique assemblages of organisms and not a simple southward displacement of today's biomes. This also means that glacial climates had their own distinctive character and were inexact analogs of the modern northern climes (Graham, 1976; Rhodes, 1984).

The oldest two local faunas were collected by Rhodes (1984) from two well-delineated, superposed, small-valley alluvial fills in a single cutbank on Chaboneau Creek, Mills Co. (Fig. 1, 19). The recovered remains were almost exclusively bones and teeth of small mammals; undoubtedly a result of the depositional environment of, and taphonomic mechanisms active in each horizon (Rhodes, 1984). This section, and 51 other vertebrate-bearing deposits, were located during an intensive survey of the Waubonsie drainage for cultural and paleontological resources (Hotopp et al., 1975; Rhodes and Semken, 1976).

The older of the two horizons, from which the Craigmile l.f. was collected, has been radiocarbon dated at 23,240 ± 535 RCYBP (DIC-1369; Rhodes, 1984). Since bone was the only datable material preserved in this horizon, the date was obtained from bone collagen (unfractionated). This then represents a minimal date for the horizon (Taylor, 1980). The Craigmile contains 31 mammalian taxa (Tables 2 and 3) represented by 173 MNI. Of these, 5 taxa (Table 3; 5 MNI) are large mammals; 4 of the 5 (including native North American *Equus* sp., one-toed horse) are extinct. The extinct *Dasypus bellus* (Simpson), beautiful armadillo, was morphologically identical to but at least twice the size of the modern *D. novemcinctus* Linnaeus, nine-banded armadillo (Auffenberg, 1957). Its occurrence in the Craigmile l.f. is one of the northernmost records of any armadillo (Simpson, 1980:85; Klippel and Parmalee, 1984). Rhodes (1984) also reports a milk tooth in the Craigmile which he tentatively assigned to *Sangamona fugitiva* Hay, stilt-legged deer, a taxon of controversial validity (Kurtén, 1979; Churcher, 1984).

Twenty-four of the 31 taxa in the Craigmile are living ILR taxa (Rhodes, 1984). The Craigmile is dominated by *M. pennsylvanicus* which represents about 50% of the recovered individuals and is almost ten times more abundant than any other micromammal. This species, together with the other open-ground indicators, account for 70% of all individuals and document the importance of grasslands in the Loess Hills environment of 23,200 years ago. The complete absence of arboreal squirrels suggests that trees were uncommon. Some groves of trees must nonetheless have been present to allow the occurrence of such forest inhabitants as *T. striatus* and *Clethrionomys gapperi* (Vigors), boreal redback vole. The area of maximum sympatry is in west central



Figs. 5-7. Areas of mammalian sympatry of 3 Wisconsinan local faunas from western Iowa.

Fig. 5. The circa 23,000 YBP Craigmile l.f., Mills Co., Ia.: 20 of 24 ILR taxa (23 of 27 living mammals) presently co-occur in the stippled area.

Fig. 6. The circa 14,800 YBP Waubonsie l.f., Mills Co., Ia.: 17 of 22 ILR taxa (18 of 23 living mammals) presently co-occur in each shaded area. ***Microtus pinetorum*** occurs only in the eastern area (hachured); ***Onychomys*** sp. only in the western (stippled).

Fig. 7. The circa 12,400 YBP Brayton l.f., Aubudon Co., Ia.: 9 of 10 ILR taxa (10 of 12 living mammals) presently co-occur in the area hachured with slanting lines. ***Phenacomys intermedius*** occurs to north in region hachured with horizontal lines.

Table 4
Biogeographic affinities of Insectivora, Lagomorpha, and Rodentia ("ILR" taxa) in western Iowa local faunas and faunules.

Local fauna or faunule	MNI of ILR taxa[a]		Number of ILR taxa[a]	Centers of distribution[b]										Indeterminate as a % of the determinate sum		Commensal as a % of the determinate sum	
				Boreomontane		Steppe		Deciduous forest		Southern		Widespread					
				% taxa	% MNI	% taxa	% MNI	% taxa	% MNI	% taxa	% MNI	% taxa	% MNI	% taxa	% MNI	% taxa	% MNI
SOUTHWESTERN IOWA:																	
Present fauna - Mills and Fremont Counties[c]	--	-	24 (2)[d]	17	--	25	--	38	--	4	--	17	--	8	--	--	--
Craigmile local fauna	163	(3)[d]	22 (2)	55	77	23	18	19	4	0	0	5	1	9	1	0	0
Waubonsie local fauna	108	(9)	20 (2)	50	72	25	6	25	22	0	0	0	0	10	8	0	0
Garrett Farm local fauna	55	(3)	15 (2)	27	27	33	53	33	18	0	0	7	2	13	5	0	0
Pleasant Ridge local fauna	60	(2)	18 (1)	22	17	33	42	33	37	0	0	11	5	6	3	0	0
Thurman local fauna	21	(8)	10 (2)	20	24	20	43	60	33	0	0	0	0	20	38	0	0
Glenwood locality earthlodge faunules:																	
Hilltop (13ML126) - 852 YBP (21 MNI O. palustris exclu.)	21	(5)	11 (1)	9	5	55	43	18	14	0	0	18	38	9	24	9	100
Hilltop (13ML155) - 698 YBP (27 MNI O. palustris exclu.)	27	(13)	15 (1)	7	4	40	37	33	37	0	0	20	22	7	48	7	100
Terrace (13ML130) - 807 YBP (21 MNI O. palustris exclu.)	20	(5)	10 (1)	10	10	20	35	40	20	0	0	30	35	10	25	10	105
Terrace (13ML124) - 735 YBP (5 MNI O. palustris exclu.)	24	(6)	15 (1)	13	8	33	42	33	38	0	0	20	12	7	25	7	21
CENTRAL WESTERN IOWA:																	
Present fauna - Audubon and Crawford Counties[c]	--	-	24 (2)	17	--	25	--	42	--	0	--	17	--	8	--	--	--
Brayton local fauna	13	(1)	9 (1)	67	78	22	15	11	8	0	0	0	0	11	8	0	0
M.A.D. sites - Boyer variant faunules (1 MNI O. palustris excluded)	25[e]	(2)	8 (2)	25	--[f]	25	--	38	--	0	--	13	--	25	8	12	4

NORTHWESTERN IOWA:																		
Present fauna - Cherokee Co.[c]	--	-	24 (2)	21	--	29	--	33	--	0	--	17	--	8	--	--	--
Cherokee l.f. (combined)	73	(9)	18 (1)	33	34	33	25	22	33	0	0	11	8	6	12	0	0
Cherokee l.f. - Cultural Horizon faunules:																	
Cultural Horizon III	16	(0)	11 (0)	27	38	27	19	27	31	0	0	18	12	0	0	0	0
Cultural Horizon II	43	(6)	13 (1)	38	37	31	21	23	33	0	0	8	9	8	14	0	0
Cultural Horizon I	14	(3)	10 (0)	30	29	50	43	20	29	0	0	0	0	0	21	0	0
Rainbow site Cultural Horizon faunules:																	
Cultural Horizon A	24[g]	(2)	7 (1)	0	--[f]	43	--	29	--	0	--	29	--	14	8	0	0
Cultural Horizon C	159[h]	(6)	8 (1)	13	--[f]	50	--	25	--	0	--	13	--	13	4	0	0
Broken Kettle West l.f., House 3 local faunule	38[i]	(6)	7 (2)	0	--[f]	57	--	14	--	0	--	29	--	29	16	0	0
Brewster local fauna	449[j]	(12)	7 (3)	0	--[f]	43	--	29	--	0	--	29	--	43	3	0	0
Phipps local fauna	498[k]	(17)	12 (3)	0	--[f]	33	--	50	--	0	--	17	--	25	3	0	0
Milford local fauna (2 MNI R. norvegicus excluded)	70[l]	(0)	14 (0)	29	--[f]	29	--	14	--	0	--	29	--	0	0	7	3

[a] Numbers in parentheses indicate either MNI's or taxa which can not be assigned to a center of distribution. Usually these represent specimens diagnosed only to genus or higher taxonomic level.

[b] Centers of distribution after Hoffmann and Jones (1970) except as noted in Table 2.

[c] The maximum potential geographic ranges of both Bowles (1975) and Hall (1981) were used to establish the taxa potentially present in each of the Iowa counties.

[d] Number in parentheses denotes the number of individuals or taxa which can not be assigned to a center of distribution.

[e] 11 MNI (41%) are *Geomys bursarius*.

[f] These faunules are severely unbalanced and show potentially strong cultural bias. The MNI percentages were thus not computed.

[g] 15 MNI (58%) are *G. bursarius*.

[h] 132 MNI (80%) are *G. bursarius*.

[i] These MNI's were calculated by Alex (1970) on a per feature basis and this number probably is greater than would be produced by our standard methods. Absence of raw data in the cited source prevents recalculation.

[j] 333 MNI (72%) are *G. bursarius*.

[k] 275 MNI (54%) are *G. bursarius*.

[l] 31 MNI (44%) are *G. bursarius*.

Wisconsin (Fig. 5) where 20 of 24 ILR taxa presently co-occur. All together, 23 of the 27 living mammal taxa should have been found in Wisconsin at the time of European settlement.

The Craigmile l.f. includes 9 taxa which no longer live in Mills County: *Sorex palustris* Richardson, water shrew; *S. arcticus* Kerr, arctic shrew; *M. hoyi; Eutamias minimus* (Bachman), least chipmunk; *Cynomys ludovicianus* (Ord), black-tailed prairie dog; *Thomomys talpoides* (Richardson), northern pocket gopher; *C. gapperi; P. intermedius;* and *Synaptomys borealis* (Richardson), northern bog lemming. All but *Cynomys* have present-day southern range boundaries far to the north or northwest of Mills County. *Cynomys* now lives on the Great Plains from Canada to Texas. When categorized by centers of distribution (Table 4), the Craigmile l.f., in striking contrast to the modern fauna of Mills Co., is strongly dominated by boreomontane ILR taxa (55%, 77% MNI). Although of quite different composition, the Craigmile l.f. has a diversity comparable (based on the number of ILR taxa in each) to that in Mills Co. today.

Analysis of the modern habits, niches, and the area of sympatry of the Craigmile species indicates that southwestern Iowa was colder in both winter and summer than today. Absolute precipitation was probably less than at present but, with reduced temperatures, effective precipitation was nearly the same. The high relative frquencies of meadow and grassland ecotypes indicates that extensive boreal grasslands, primarily moist meadows, dominated the landscape. The remaining taxa show that mixed groves of deciduous and coniferous trees with their brushy margins persisted on favorable exposures and provided a weak mosaic of boreal and cool/mesic habitats (Rhodes, 1984).

The Waubonsie l.f. is from an overlying horizon in the same cutbank as is the Craigmile (Fig. 1, 19). Finely disseminated charcoal from this horizon has been radiocarbon dated at 14,830 + 1060, − 1220 RCYBP (DIC-1688; Rhodes, 1984). Another date of 14,430 ± 1030 RCYBP (I-7496) was determined on charcoal fragments which had not been pretreated to remove humic acids and therefore may be less reliable. The Waubonsie l.f. contains 23 mammalian taxa (Tables 2 and 3) and 118 MNI. Only one specimen, an unidentifiable fragment of an artiodactyl molar, is a large mammal (Rhodes, 1984). *Microtus pennsylvanicus* (27% MNI) was reduced substantially in relative abundance from the Craigmile but still was three times more abundant than any other mammal in this local fauna. Grassland, represented by 40% of the individuals, was still important but less so than previously. *Tamiasciurus hudsonicus* (Erxleben), red squirrel, is present and documents the increased importance of trees circa 14,800 years ago.

Seventeen of the 22 Waubonsie l.f. ILR taxa (18 of 23, all mammals) live together today in south central Minnesota and in west central Wisconsin (Fig. 6). *Onychomys* sp., grasshopper mouse, is present only in the Minnesota area; *Microtus (Pitymys) pinetorum* (Le Conte), woodland vole, only in the Wisconsin area. When the Waubonsie ILR taxa are divided by centers of distribution (Table 4), boreomontane taxa (50%, 72% MNI) again dominate and the percent composition is similar to that in the Craigmile (55%, 77% MNI). However, deciduous forest taxa markedly increased (25%, 22% MNI) over their representation in the Craigmile (19%, 4% MNI). Rhodes (1984) notes that increased forest development could relate to either (or both) climatic change or microniche expansion in response to greater topographic relief created by loess accumulation between 24,000 and 14,000 YBP. Eight of the 22 Waubonsie small mammals no longer live in Mills County: *S. arcticus; T. hudsonicus; T. talpoides; Onychomys* sp.; *Neotoma* sp., woodrat; *C. gapperi; P. intermedius;* and *Microtus xanthognathus* (Leach), yellow-cheeked vole. All live today to the north or northwest of Mills County.

The Waubonsie l.f. has similar areas of sympatry to the Craigmile l.f. and also represents colder winter and summer conditions than those at present. Precipitation was similar to that at the time of the Craigmile but probably more effective. A marked increased in forest or brushland vegetation provided a larger niche for forest-edge micromammals but boreal grasslands were still important (Rhodes, 1984).

The youngest of the three Wisconsinan local faunas is that reported by Dulian (1975) from the Brayton pit, Audubon Co. (Fig. 1, 15). In addition to vertebrates, the Brayton local biota (l.b.) includes pollen, plant macrofossils, and molluscs. Associated organic debris has been radiocarbon dated at 12,420 ± 180 RCYBP (I-8015; Dulian, 1975; Baker et al., 1980). It contains 16 taxa (Tables 2 and 3; 20 MNI) of which 6 (6 MNI) are large mammals. These megamammals are represented by some taxa which survived in Audubon Co. until European settlement (*Bison* sp.), others that were disjunct at the time of settlement (*Rangifer* sp., caribou), and those that became extinct (*S. cavifrons; Cervalces scotti* [Lydekker], stag-moose; *Equus* sp.; and *Mammuthus ?jeffersonii*). The Brayton l.b. was recovered from the sediments in a low Wisconsinan terrace of the East Nishnabotna River. The correspondingly different taphonomy of this site, compared to the two Mills Co. local faunas which were found in small valley alluvium, accounts for the higher proportion of large mammal remains found at Brayton. Because the Brayton l.b. was deposited contemporaneously with the recession of the Des Moines lobe (at 12,400 YBP located about 190 km to the north), it permits paleoecological interpretation of the climate directly associated with glacial recession in Iowa and the Pleistocene megafauna just prior to its demise.

Of the 10 Brayton ILR taxa, 3 are no longer found in Audubon County: *T. hudsonicus, C. gapperi,* and *P. intermedius*. However, all 10 of these ILR taxa occur in the Waubonsie l.f. and only *T. hudsonicus* is absent from the Craigmile. The Brayton sympatry is centered in west central Wisconsin and southeastern Minnesota (Fig. 7). This area contains 9 of the 10 fossil micromammals in this site (10 of 12 living mammals). Hence, the paleoenvironmental interpretation of the three local faunas is similar. The Brayton l.b. sample size is small and relative frequencies by centers of distribution may be misleading. Even so, this abundance data (Table 4) indicates that the late Wisconsinan environment in Audubon Co. was much more boreal than today and comparable with that of the two earlier Mills Co. local faunas. The identified Brayton species also suggest that there was a mosaic of boreal forest, deciduous forest, and grassland in the landscape.

Fortunately, collateral evidence from plant fossils at the Brayton locality is more informative (Dulian, 1975; Baker et al., 1980; Semken and Falk, in press). The pollen spectrum associated with the microvertebrate horizon is similar to that of the late-glacial spruce pollen zone of the north central United States. The substantial amounts of herbaceous pollen (30%) indicates that the forest was not closed (Baker et al., 1980) and that savanna conditions may have been present. Plant macrofossils show that a mixed boreal/deciduous forest association was locally developed (Dulian, 1975). When taken as a whole the biota of southwestern Iowa of 12,400 YBP probably more resembled the prairie/forest ecotone of northern Minnesota than that indicated in the sympatry of the small mammals (Fig. 7). During this period of final retreat of the Wisconsinan glacial ice from Iowa, forest groves were both larger and more dense, and deciduous trees were relatively more abundant in the biota, than during the preceding full-glacial.

The Wisconsinan Environment

These three local faunas indicate that the Wisconsinan had colder year-round temperatures and decreased absolute precipitation. Effective moisture may have been similar to that of the present. None contain tundra-specific taxa, but all show a strong, cold steppe component. Each local fauna has fewer temperate/mesic elements than presently occur in the area but representatives of this group did persist

in the region during glacial time. The disharmonious nature of each indicates that boreal biomes did not move southward as entities during the Wisconsinan, but rather that individual species responded to glacial climatic conditions by independent range adjustments (Graham, 1979; King and Graham, 1981).

Together with the large mammals found throughout the Loess Hills, these faunas suggest that the Wisconsinan landscape was dominated to a greater or lesser extent by boreal grassland. Structurally, the vegetation probably was a parkland like that found today near the prairie forest border in southern Manitoba and Saskatchewan. Both the mega- and micromammal components were dominated by boreal grazers but woody vegetation was sufficient to support a smaller, largely boreal browsing component. The scarcity of deciduous forest species, common to the southeast both then and now, suggests that hardwoods were rare in the parkland, particularly around 23,000 RCYBP. Forest cover was increasingly more deciduous in nature toward the end of the Wisconsinan and apparently was well established by 10,000 YBP.

THE WISCONSINAN/HOLOCENE TRANSITION: A TIME FOR CHANGE

The climatic changes centering around 10,000 years ago, from the last glacial to the present interglacial climate had a profound effect on the mammalian fauna of the Loess Hills. Even though suitable alluvial sediments are present in the Loess Hills, the currently published faunal prehistory has a 4,000 year gap between 12,400 and 8,400 YBP. Nonetheless, it can be inferred from localities in the surrounding regions that as the climate became warmer, boreal small mammals gradually retreated northward and austral taxa reoccupied their former ranges (Lundelius et al., 1983; Hudak, 1984). The most spectacular biotic effect at the end of the Wisconsinan was the sudden collapse of the megafaunal community and the extinction of most of its members. This remarkable extinction event defines the end of the Rancholabrean land mammal age and corresponds with the generally accepted end of the Wisconsinan glacial stage. It is the most accessible extinction event to study of any in the geologic record and its cause has been of intense interest to layman and professional alike. Either climatic change or invasion of North America by Paleo-Indian big-game hunters has been proposed as the primary cause for the collapse. Because of the 4,000 year break in available faunal sites, discussion of this debate is beyond the scope of this paper. The interested reader is referred to Martin and Wright (1967), Martin and Klein (1984), and Mead and Meltzer (1985).

The Wisconsinan sites in western Iowa provide evidence supporting the concept of rich, boreal grasslands which were grazed by the megamammal fauna (Guthrie, 1968; 1984). By 8,400 YBP, when analyzed sites again are available, this glacial-age biome had disappeared from the state. As Guthrie (1968; 1984) suggested, and as examination of Table 1 reveals, this environmental change would most heavily effect the large grazers. Their prime habitat, the boreal grasslands, had been eliminated by climatic change at the end of the Wisconsinan.

Although the mammalian fauna changed most rapidly around 10,000 years ago, the small mammals were constantly undergoing range adjustments both before and after the glacial/interglacial transition. Although of smaller magnitude, this process continued throughout the Holocene (Semken, 1983; 1984). These range adjustments undoubtedly were responses to the smaller-scale climatic fluctuations within both the glacial and interglacial climatic regimes.

OF MAN AND MAMMAL IN THE HOLOCENE OF THE LOESS HILLS

Mammals of Holecene age (the interglacial in which we now live) have been collected at sites with both archeological and non-cultural contexts. These sites are almost invariably located in or near stream and gully bottoms. The uplands are barren. This is a consequence of the cessation at the end of the Wisconsinan of the accumulation of significant thicknesses of wind-transported loess on the uplands. When deposition halted, erosion, weathering, and soil development became the dominant upland processes. All are detrimental to the preservation of bone. Fortunately the eroded material was redeposited in lowland areas where conditions often were favorable for preservation of fossils. Periods of aggradation have alternated with periods of degradation during the Holocene of the Loess Hills. Each erosional episode has left irregularly distributed remnants in the small valleys of the preceding aggradational events (alluvial fills). These alluvial fills are well-documented in the Loess Hills and collectively referred to the De Forest Formation; each major fill unit has been designated a separate lithologic member (Daniels et al., 1963; Hoyer, 1980a; Thompson and Bettis, 1980; Bettis and Thompson, 1981; 1982a). The De Forest Fm. fills, bounded by erosional unconformities, have preserved many cultural and non-cultural faunal accumulations.

Holocene mammalian faunas of the Loess Hills, both archeological and non-cultural, have three characters in striking contrast to Wisconsinan faunas: (1) their megamammal component is impoverished by the terminal Pleistocene extinction, (2) *Bison* frequently is present in overwhelming numbers, and (3) the micromammal component is similar to that of today in species composition. Because the Holocene mammalian fauna is similar to that present when European farmers settled Iowa, these sites have generally not interested the professional paleontologist (Semken, 1983). Pioneering researchers such as Calvin and Shimek mention unusually prolific accumulations of Holocene-age bone only in passing (e.g. Shimek, 1910b:408-410) and devoted their full attention to the extinct megafauna. None of their Holocene sites have been revisited.

Early Holocene (10,000 - 8,490 YBP)

Even though an early Holocene alluvial fill (Watkins Member, De Forest Fm.) is preserved as scattered remnants in the small valleys of the Loess Hills (Bettis and Thompson, 1982a) and undoubtedly is fossiliferous, no mammalian remains have been reported from it. This fill, representing the time period encompassing the Pre-Boreal and Boreal climatic episodes, deserves greater attention because it is in it that the faunal transition at the glacial/interglacial boundary will be found.

Middle Holocene (8,490 - 5,060 YBP)

The middle Holocene, as used herein, contains only the Atlantic climatic episode of Wendland and Bryson (1974). During this time, erosion was the dominant process in the small watersheds of the Loess Hills. Fortunately, these sediments (Corrington Member, De Forest Fm.) accumulated in alluvial fans where the small valleys debouch onto major flood plains (Bettis and Thompson, 1982a).

One such Corrington Member fan has been excavated, the Cherokee Sewer site, 13CK405, Cherokee Co. (Fig. 1, 6; Anderson and Semken, 1980) and it contained a stratified, cultural and faunal sequence. Waterscreening on 1.6 mm screen of bulk matrix and normal archeological excavation techniques resulted in the recovery of 27 different taxa (listed as 3 stratigraphic faunules in Tables 2 and 3) represented by 128 MNI (Semken, 1980; Pyle, 1980). The Cherokee local fauna was separated into three successional faunules (Semken, 1980) radiocarbon dated circa 8,400 (III), 7,300 (II), and 6,350 (I) YBP (22 charcoal dates; Hoyer, 1980b:64-66). Each faunule was associated with *Bison* processing activities which were concentrated in the tops of distinct paleosols. The presence of 18 such paleosols, dated between 10,000 and 2,500 YBP indicates that the fan was constructed during short, intermittent depositional episodes. Each episode was followed by a variable length period of stability and soil development

(Hoyer, 1980b). Thus, the Cultural Horizon, III, II, and I faunules of the Cherokee l.f. each reflect climatic conditions associated with intervals of depositional quiescence during middle Holocene time. As such, the faunules, individually or collectively, indicate those environments which were chronologically dominant during the altithermal (usage after Flint, 1971:525) in this region.

The Cherokee l.f., 19 ILR taxa, reflects a community that is almost as diverse as the 26 member ILR micromammal community (using maximum ranges of both Bowles, 1975, and Hall, 1981) now residing in the county (Semken, 1980). This combination in the Cherokee l.f. of high species diversity with the presence of components from the prairie, forest, arboreal, meadow, and aquatic communities, indicates that sampling was reasonably complete. Collectively, the faunules of the Cherokee l.f. reflect the range of possible altithermal conditions on the northeastern plains of the United States. As such, the local fauna is useful as an "average" for general comparison to other Atlantic episode local faunas.

Seventeen (65%) of the 26 modern resident ILR species are recorded in one or more faunules of the Cherokee local fauna. The 65% resemblance between the faunal lists of the living and fossil species suggests that the paleoecological interpretations may be described legitimately as variations of present conditions. Species common to an upland prairie environment with a gallery forest along major watercourses characterize Cherokee Co. both now and during the Atlantic episode. However, the fossil assemblage is distinct from that in the area today. Four of the 9 modern ILR taxa missing from the Cherokee l.f. are forest associated species - *Marmota monax* Linnaeus, woodchuck; *Sciurus niger* Linnaeus, fox squirrel; *S. carolinensis;* and *E. dorsatum.* Two other recent taxa not recorded in the Cherokee l.f. are prairie species - *Spermophilus tridecemlineatus* (Mitchell), thirteen-lined ground squirrel; and *Perognathus flavescens* Merriam, Plains pocket mouse. The prairie-related *L. townsendii,* also absent from the Cherokee l.f., is regarded by Bowles (1975) as a recent addition to the Iowa fauna whose immigration was permitted by land clearance for agriculture. Bowles (1975) also considers agricultural mowing and grazing to have increased the short-grass habitat preferred by *S. tridecemlineatus.* Although Hall (1981) indicates *T. striatus* to be absent from Cherokee Co. today, Bowles (1975) records it as present and its occurrence in the Cherokee l.f. is unremarkable. The modern residents which are not present in the Cherokee l.f. thus indicate that woodlands are more abundant, or at least more dense, in Cherokee Co. today than they were during the altithermal.

The 2 fossil mammals which are present in the Cherokee l.f. but do not live in the county today also support the concept that woodlands are more abundant now than during the middle Holocene. *Perognathus hispidus* Baird, hispid pocket mouse, is today found to the west and southwest of Cherokee and indicates more open country than that at present. *Tamiasciurus hudsonicus* is today found primarily to the north of the site where it occupies open, deciduous gallery forests in its Iowa range. Its presence is in accord with a more park-like gallery forest during the Atlantic.

The presence of *T. hudsonicus, M. hoyi,* and *Synaptomys cooperi* Baird, southern bog lemming, in the Cherokee l.f. suggests that summer highs were less extreme during the Atlantic. Thus, the middle Holocene of northwestern Iowa can be interpreted as a period with less effective moisture and cooler summers than in the area today. This configuration is best explained by increased dominance of cool dry Pacific air during Atlantic episode summers in the region (Wendland, 1980).

The 3 faunules of the Cherokee l.f. have been compared to each other by two methods: (1) relative abundance of individuals and (2) area of sympatry (Semken, 1980). Although the samples on horizons III and I were small, both methods produced an interpretation of increasing aridity through the altithermal. When recalculated herein (to standardize all sites to rhe same biogeographic sources), the number of species with a center of distribution in the steppe and their relative abundance of individuals (Table 4) increased progressively from Cultural Horizon III (8,400 YBP) to Cultural Horizon I (6,530 YBP). There was a corresponding decrease of boreomontane forms. Analysis of preferred habitats confirms the above; prairie ecotypes expand at the expense of woodland while meadow ecotypes remained essentially constant (Semken, 1980:88, Fig. 3.4).

The sympatries herein differ somewhat from those in Semken (1980; 1983) because both different range maps and techniques were used but they confirm his analysis of increasing desiccation with time. His sympatries are all displaced a little to the east of those herein and thus suggest slightly more mesic conditions for each horizon.

The replotted area of sympatry for the 8,400 YBP Cultural Horizon III faunule (Fig. 8) is defined by 11 ILR taxa with 16 MNI and shows that the faunule is harmonious. It contains all 13 mammalian taxa and, even though Cherokee is not contained (it would have been if the distribution of *T. striatus* was mapped after Bowles, 1975), it surrounds Cherokee on the east, north, and south (Fig. 8). The presence of the large semispecies of *Blarina brevicauda* (Say), short-tailed shrew, - *B. b. brevicauda* (Say) - in the horizon III faunule suggests that the eastern outlier of the area of sympatry in central Illinois is spurious; since only the smaller semispecies *B. b. talpoides* (Gapper) now occurs there (Jones et al., 1984). Unfortunately, the modern distribution of these two *B. brevicauda* semispecies is poorly known (Moncrief et al., 1982; Jones et al., 1984) and can not be used to further constrain the interpretation.

The 7,300 YBP Cultural Horizon II sympatry (Fig. 9; 14 ILR taxa, 43 MNI) shows this faunule to be disharmonious. It consists of three disjunct areas with 13 of 14 ILR taxa each (17 of 18, all mammals). *Perognathus hispidus* is missing from the two eastern areas, *T. hudsonicus* from the southwestern. The occurrence in the faunule of *P. hispidus,* which presently is restricted to prairies west of the Missouri River, produces this disharmonious association and moves the sympatry of the faunule to the west. Because only the large semispecies *B. b. brevicauda* has been recovered in the horizon II faunule, the central Illinois area can again be excluded.

The 6,350 YBP Cultural Horizon I faunule also is disharmonious. Its sympatry (Fig. 10; 10 ILR taxa, 14 MNI) has two disjunct areas, one of which lies to the north and the other to the southwest of Cherokee. The eastern boundary of each is well to the west of that for either Cultural Horizon II or III. The continued presence of *P. hispidus* again produces this disharmonious association (9 of 10 ILR taxa, 12 of 13 all mammals excluding 2 MNI *Canis familiaris* Linnaeus, domestic dog). Although not as pronounced as the Wisconsinan disharmonious associations, this pattern probably indicates that Atlantic paleoclimates were not exactly like any seen today. As the mammals continued their individualistic range adjustments from the Wisconsinan, combinations of climatic parameters (slightly different than today's) could allow the ranges of now disjunct taxa to overlap. The small geographic separation of the areas of sympatry of the horizon I faunule suggests that these differences need not have been of large magnitude. A sympatry to the west of Cherokee is compatible with paleopedologic evidence for substantially increased aridity during formation of the paleosol comple (5/6) associated with Cultural Horizon I (Hoyer, 1980b). The general northwestward shift of the sympatries with decreasing age also implies a decrease in mean high summer temperatures at the same time that effective moisture was being reduced. This combination is best explained by increasing the length of time that cool, dry Pacific air covered the region during altithermal summers (Wendland, 1980).

Late Holocene (5,060 YBP - Present)

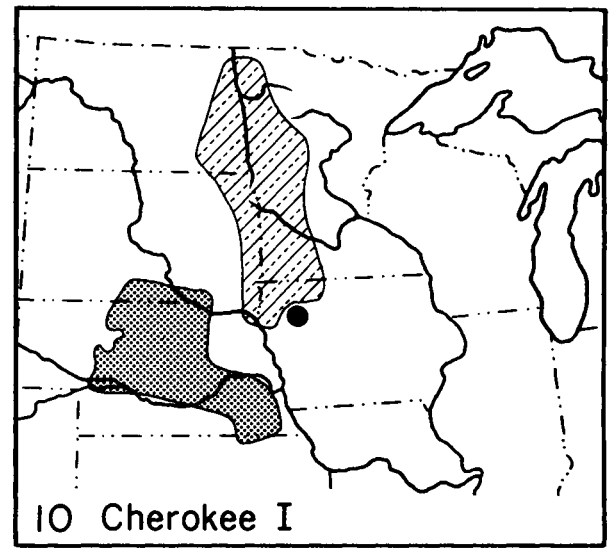
The "climatic episode" schema is particularly useful for subdivision of the late Holocene chronology and we have followed Wendland's (1978) usage. Lithostratigraphic assignment of depositional horizons

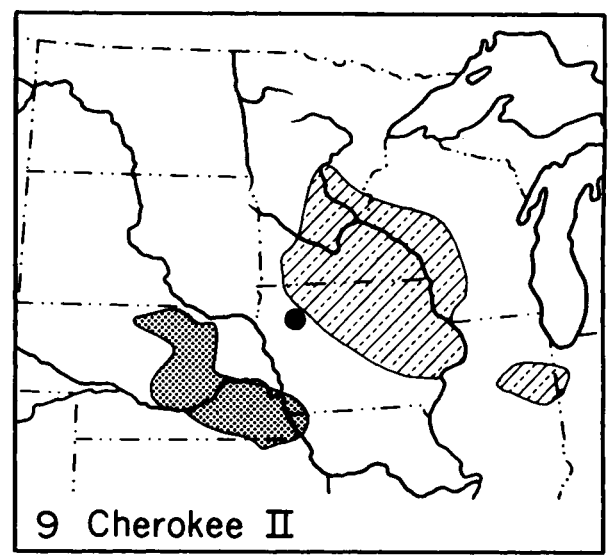
to members of the De Forest Fm. (Daniels et al., 1963; Bettis and Thompson, 1982a) is made only when the alluvial fills are identified in the original citation or in Bettis and Thompson's (1982b) catalog. The larger regional analysis of paleoclimate and vertebrate paleontology is available in Semken (1983) and Semken and Falk (in press).

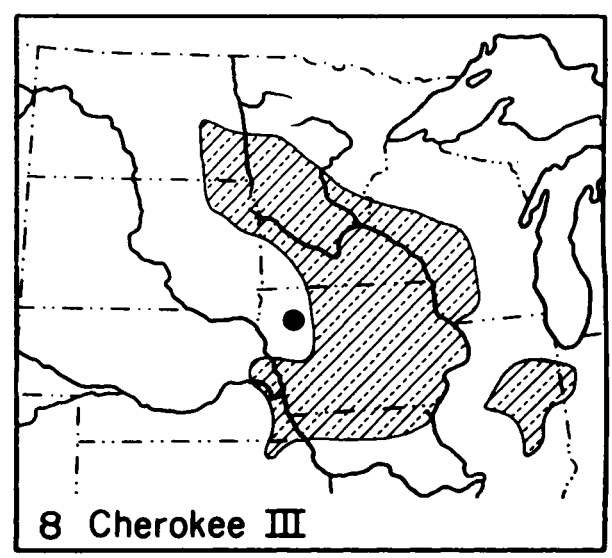
"Sub-Boreal" (5,060 - 2,760 YBP) — The only local fauna in western Iowa from the Sub-Boreal climatic episode is the non-cultural Garrett Farm l.f. (Fig. 1, 19) found in the Waubonsie watershed of Mills Co. (Fay, 1978b; 1980). Systematic waterscreening on 1.6 mm screen of bulk samples by Fay resulted in the recovery of 21 taxa (62 MNI) from four successional faunules within a 6.6 m alluvial sequence (Fay, 1978b). Bettis and Thompson (1982b) have assigned this alluvium to the Hatcher Member of the De Forest Formation. Three radiocarbon dates were obtained on disseminated charcoal fragments at this site (Fay, 1978b; pers. comm., 1982): 3,600 ± 305 RCYBP (DIC-2521) from the basal gravel of the fill, 3,590 ± 75 RCYBP (DIC-2520) from sandy silt about 0.5 m above the basal gravel, and 3,400 + 280, − 290 RCYBP (DIC-877) on a composite sample picked from residues both from the basal gravel and 3.5 m of the overlying sandy silt.

When the 17 ILR taxa (58 MNI; Table 2) are categorized by centers of distribution, the Garrett Farm l.f. is composed of 33% steppe, 27% boreomontane, 7% widespread, and 33% deciduous forest species (Table 4). This contrasts to a modern presettlement distribution of 25% steppe, 17% boreomontane, 17% widespread, 38% deciduous forest, and 4% southern species and indicates that Sub-Boreal climates of southwestern Iowa were associated with less effective precipitation than characteristic of the area today. These values are different from those of Fay (1980) because he used the entire fauna whereas we have selected only the ILR taxa in order to standardize site comparisons. When these figures are recalculated to a percent of the minimum number of individuals from Fay's (1980) faunal list (steppe - 53% MNI, boreomontane - 27% MNI, widespread - 2% MNI, deciduous forest - 18% MNI), the dominance of steppe forms is even more pronounced. Unfortunately, comparable MNI data is not available for a modern presettlement local fauna. Thus, grasslands appear to have occupied a greater proportion of the landscape during Sub-Boreal time than today. The diagnosis of *Neotoma micropus* Baird, southern Plains woodrat, in the Garrett Farm is based on a single molar and Fay (1978b) considers this diagnosis uncertain. Because of this, we have assigned the molar to *Neotoma* sp. for the calculation of abundance data and the preparation of sympatry maps.

Because the narrow range of radiocarbon dates indicates rapid deposition, the sympatry has been plotted for the combined faunal list from all four Garrett Farm faunules (Fay, 1978b; 1980). This disharmonious sympatry (Fig. 11) contains 16 of 17 ILR taxa (20 of 21 taxa all mammals). *Clethrionomys gapperi* is absent from the area of sympatry. At a maximum, only 14 of 17 ILR taxa occur with it in southeastern Minnesota. Three of the Garrett Farm taxa are no longer found in Mills County: *Onychomys leucogaster* (Wied-Neuwied), north-







Figs. 8-10. Areas of mammalian sympatry of the 3 faunules of the Cherokee l.f., 13CK405, Cherokee Co., Ia.

Fig. 8. The circa 8,400 YBP Cultural Horizon III faunule: 11 of 11 ILR taxa (13 of 13 mammals) presently co-occur in both hachured areas.

Fig. 9. The circa 7,300 YBP Cultural Horizon II faunule: 13 of 14 ILR taxa (17 of 18 mammals) presently co-occur in each shaded area. ***Tamiasciurus hudsonicus*** occurs only in the eastern two areas (hachured); ***P. hispidus*** only in the westernmost (stippled).

Fig. 10. The circa 6,350 YBP Cultural Horizon I faunule: 9 of 10 ILR taxa (12 of 13 wild mammals) presently co-occur in each shaded area. ***Microsorex hoyi*** occurs only in the northern area (hachured); ***P. hispidus*** only in the southern (stippled).

ern grasshopper mouse; *Neotoma* sp.; and *C. gapperi.*

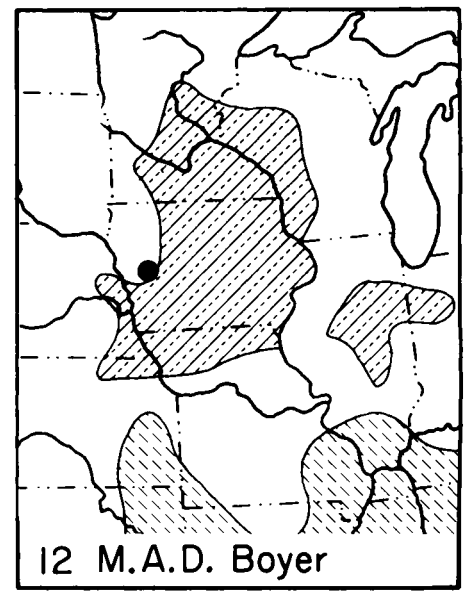
Fay (1980) describes co-occurrence of two phena of *Blarina* in the Garrett Farm local fauna. His diagnoses were based on the mandibular parameters of Graham and Semken (1976). Jones et al. (1984) confirmed the identification of *B. b. kirtlandi* Bole and Moulthrop (equals their semispecies *B. b. talpoides* in part) using an independent set of dental characters. The single *B. "carolinensis"* specimen (probably equals *B. hylophaga* Elliot of Moncrief et al., 1982) was not suitable for their analysis because it is edentulous. The co-occurrence of these two phena as fossils supports the neontological assignment of the phena to distinct species. Furthermore, Moncrief et al. (1982) and Jones et al. (1984) report that, in the area encompassed by northeastern Kansas, southeastern Nebraska, southern Iowa, and northern Missouri, three *Blarina* phena coexist: *B. hylophaga (B. carolinenis* in part), *B. brevicauda brevicauda,* and *B. b. kirtlandi (B. b.* semispecies *talpoides* in part). Both the Garrett Farm sympatry and Mills Co. are today within this zone of *Blarina* phenetic diversity.

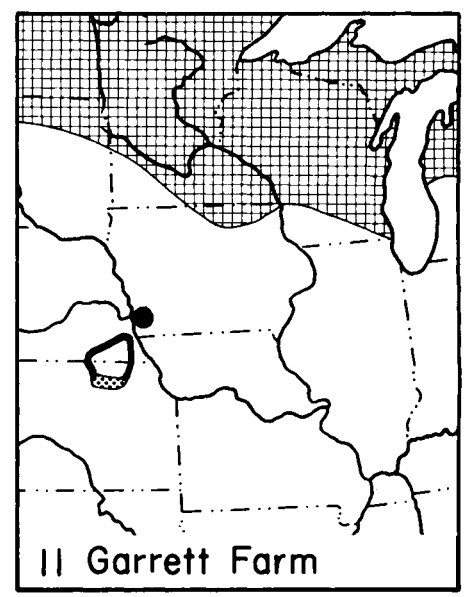
The presence of *Neotoma* in the Garrett Farm l.f. may not be directly related to prevailing Sub-Boreal climate. This taxon often prefers to nest in crevices of talus accumulations or in bedrock caverns (Schwartz and Schwartz, 1981:211-216). It might therefore only indicate that suitable home sites in the Pennsylvanian limestone bedrock, which makes up the base of the Missouri River bluffs in Mills and Fremont Counties (Udden, 1903), were either exposed or had been exhumed by the fluvial regime during Garrett Farm time. However, *Neotoma* also has been reported from eastern Iowa (Willard Cave, Delaware Co.; Eshelman, 1971) during the Holocene between 3,500 and 1,255 YBP (Bender et al., 1973a; 1973b) from well north of its modern range. Nonetheless, identical interpretations are made because 15 of 16 ILR taxa (excluding *Neotoma*) co-occur in the outlined area including and north of the area of sympatry (Fig. 11).

The best Garrett Farm area of sympatry (with or without *Neotoma*) lies to the southwest of the site and thus reinforces the interpretation of more xeric conditions in the Missouri Valley during the Sub-Boreal. However, the paleoenvironment at Garrett Farm cannot be identical to that in this area (Fig. 11) because *C. gapperi* is disjunct to the north. However, this taxon was a resident of Mills Co. as late as 735 YBP (Semken, 1983). Disharmonious faunas, characteristic of Wisconsinan associations, clearly persisted through the altithermal, and final adjustment from altithermal to modern conditions must post-date Garrett Farm time (Fay, 1980). Later Holocene local faunas may show displacement of their areas of sympatry away from their collection sites but the disjunct species are usually found in only one direction from the sites and the faunas are usually harmonious.

"Sub-Atlantic" (2,760 - 1,680 YBP) — Two sites, both archeological, have been reported from the Sub-Atlantic episode in western Iowa: the Rainbow site, Plymouth Co. (Fig. 1, 8) and the M.A.D. sites, Crawford Co. (Fig. 1, 11). Both are in stratified alluvium and the accumulation of both cultural materials and alluvium apparently continued uninterruptedly at least into the younger Scandic episode and at the M.A.D. site into the Neo-Atlantic.

The report on the M.A.D. sites, 13CF101 and 13CF102, Crawford Co. (Fig. 1, 11) is available only as a preliminary draft (Benn, 1981a) but cultural materials indicate that these sites were erratically occupied from an aceramic period (Late Archaic or Early Woodland) into late Late Woodland time (Benn, 1981b). The two sites are contained in main valley alluvium of the Boyer River at Denison, Iowa, and are laterally separated by a younger (Historic) paleochannel (Bettis, 1981a:IIA-21). Only one micromammal taxon (6 of 40 MNI) was discovered during excavation; waterscreening (1.6 mm screen; K. B. Pyle, pers. comm., 1985) of selected bulk-samples produced the remainder (Pyle, 1981). Summing the MNI's as reported for each analytical unit by Pyle (1981), the combined local fauna has 18 mammalian taxa (84 MNI). Sixteen radiocarbon dates were obtained from charcoal associated with cultural levels at this locality, they range from 2,470 to 1,085 YBP (Benn, 1981b).





Figs. 11-12. Areas of mammalian sympatry.

Fig. 11. The circa 3,600 YBP Garrett Farm l.f., Mills Co., Ia.: 16 of 17 ILR taxa (20 of 21 mammals) presently co-occur in the stippled area. If *Neotoma* sp. is excluded 15 of 16 ILR taxa co-occur in the outlined area. *Clethrionomys gapperi* occurs in the cross-hatched region.

Fig. 12. The circa 2,000 - 1,200 YBP combined Boyer variant faunules, M.A.D. sites, 13CF101 and 13CF102, Crawford Co., Ia.: excluding *O. palustris,* 10 of 10 ILR taxa (14 of 14 wild mammals) presently co-occur in both hachured areas to the north. *Oryzomys palustris* occurs to south in region hachured with broken lines.

The "aceramic" Late Archaic/Early Woodland (prior to 2,500 YBP) and the "Valley" variant (about 2,500 to 2,000 YBP) occupations both yielded faunal remains but the samples are too small to interpret. The aceramic horizon (2 taxa, 2 MNI) does contain the only M.A.D. record of *T. hudsonicus* (now occurring in Iowa only to the north and

east of M.A.D.), and suggests that suitable gallery forest habitat was present along the Boyer River at this time. The 2 Valley variant faunules (11 taxa, 19 MNI) are composed of taxa also found in the overlying Boyer variant faunules (discussed below). *Spermophilus franklinii* (Sabine), Franklin's ground squirrel, was found only in this level. Notably, they contain the oldest report in the midcontinent of *O. palustris,* a probable commensal pest associated with aboriginal agriculturalists (Pyle, 1981).

The 4 "Boyer" variant faunules from M.A.D., combined to insure adequate sample size, date from about 2,000 YBP to sometime between 1,500 and 1,200 YBP (Benn, 1981b). Thus, they represent an "average" for Sub-Atlantic/Scandic conditions. Excluding the probable commensal *O. palustris* (1 MNI), 10 ILR taxa (27 MNI; Table 2) were recovered in association with Boyer variant horizons (Pyle, 1981). All are consistent with a mixed tall-grass prairie and gallery forest association along the Boyer valley. When the ILR taxa are sorted by centers of distribution, the M.A.D. Boyer variant faunules reveal a slightly larger boreomontane component, at the expense of deciduous elements, than today's mammalian fauna (Table 4). Over 40% of the individuals in the local fauna are *Geomys bursarius* (Shaw), Plains pocket gopher. Because this taxon was intensively exploited as part of the subsistence base (Pyle, 1981; Semken, 1981), the composition of the biota on a percent MNI basis is unreliable for paleoenvironmental reconstruction. The sympatry of the 10 ILR taxa (excluding *O. palustris;* Fig. 12) shows the fauna to be harmonious and includes the M.A.D. site at its western edge. All 14 mammalian taxa (52 MNI excluding 1 MNI *O. palustris* and 3 MNI *C. ?familiaris*) co-occur in this area of sympatry. This sympatry indicates that "average" Sub-Atlantic/Scandic conditions were generally similar to but possibly more mesic than those in the area today. A well-developed riparian gallery forest was imbedded in a prairie setting. The area thus could have resembled its appearance before the deforestation at the time of European settlement.

The other recorded Sub-Atlantic site is the Rainbow site, 13PM91, Plymouth Co. (Fig. 1, 8; Benn, 1981c). It contains more than two dozen stratified cultural components buried in alluvium of the Mullenix Member, De Forest Fm. along Held Creek (Bettis and Thompson, 1982a). Family bands of Plains Woodland people occupied the site during fall and winter seasons (Falk, 1981) between 1,760 and 1,290 YBP (21 radiocarbon age determinations on charcoal; Benn, 1981d; Bettis and Thompson, 1982b). The Sub-Atlantic/Scandic episode boundary, which falls midway in this interval, is not marked by any major lithostratigraphic discontinuity at the Rainbow site (Bettis, 1981b).

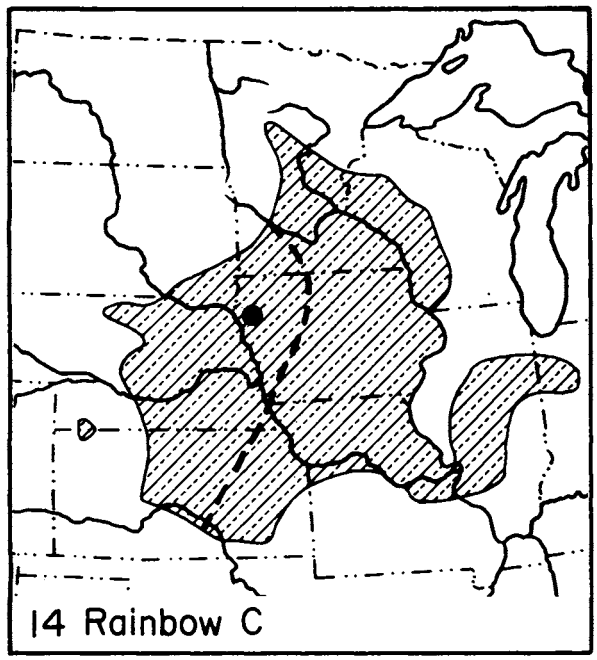
These bands subsisted on a wide variety of native foods and cultigens, the fossils of which are preserved in both cultural and non-cultural fill. Although not bulk-sampled and waterscreened, systematic selection of flotation samples and careful excavation techniques both yielded adequate material for paleoenvironmental analysis. Analyses of the botanical material (Benn, 1981e), molluscs (Baerreis, 1981), and vertebrates (Falk, 1981; Semken, 1981) provided a multidisciplinary but slightly conflicting interpretation of this time in western Iowa. The botanical evidence primarily is based on the relative abundance of *Stipa* (feathergrass), *Eupatorium* (Joe-Pye-weed and boneset), and chenopods (goosefoot and its allies). A pattern reflecting alternating drought and rainfall, characteristic of the plains, is present throughout the sequence. The chenopods seem to be correlated with either human or natural disturbance at the site while the curves for *Stipa,* a prairie grass, and *Eupatorium,* a forest forb, show a reciprocal relationship. *Stipa* generally predominates over *Eupatorium* in the lowermost portion of the section while the reverse is true above. This suggests an increase in forest cover and a change from "drier" to "more moist" conditions circa 1,600 YBP. This trend is the expected one across the Sub-Atlantic/Scandic transition in western Iowa.

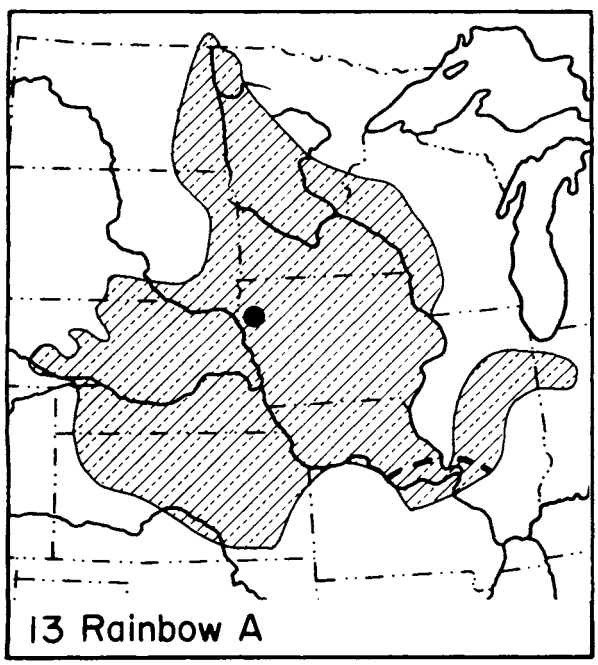
The gastropod assemblage from Rainbow is more diverse than that in modern leaf litter samples in the area (Baerreis, 1981) and the relative abundances of species within each level indicate that woodlands were more strongly developed during the entire period of site occupation (Sub-Atlantic/Scandic) than today. Baerreis (1981) interprets this to result from more precipitation than that at present. Size analysis of three Rainbow mollusc species suggested that the oldest horizons recorded the maximum precipitation in the Rainbow sequence (in contrast to the seed analysis) but that the climate was both warmer (longer growing season) and more moist (increased winter precipitation) than today over the entire period of occupation.

Despite the lack of waterscreening, careful excavation led to the recovery of mammal fossils from all cultural horizons in the Rainbow site. The combined local fauna, recalculated from Semken's (1981) raw data and Falk's (1981) summary tables to represent the number of individuals in each gross cultural horizon (A-D), consists of 22 mammalian taxa (246 MNI; Falk, 1981; Semken, 1981). Insectivores were not recovered but probably were missed because of the lack of bulk waterscreening. All Rainbow l.f. mammals probably were resident in Plymouth Co. at the time of European settlement. Only two units, Cultural Horizons A (1,760 - 1,695 YBP, in the Sub-Atlantic) and C (1,410 - 1,350 YBP, in the Scandic) produced sufficient quantities of bone for detailed comment (Tables 2 and 3); all taxa in B and D are represented in the discussed horizons. The 8 taxon ILR sample (26 MNI) from Cultural Horizon A is dominated by *G. bursarius* and individuals of this taxon (15 of 26) represent 58% of the fauna. *Geomys bursarius* undoubtedly was harvested as part of the subsistence base (R. Alex, pers. comm., cited in Dallman, 1983:28; Semken, 1981) and its abundance in horizon A undoubtedly is disproportionate to its actual percent composition in the paleobiota. The presence of *S. niger* and *C. canadensis* support the presence of either woodlands or an extensive gallery forest as predicted from both the molluscs and plant remains. *Synaptomys cooperi* was erroneously reported from this horizon because of a transcription error (Semken, 1981) and is herein excluded. If all vertebrates (fish, etc.) are included in the sample (Falk, 1981), the woodland association is reaffirmed and the Sub-Atlantic environment can be characterized as diverse with stream, stream-edge, and grassland communities also present.

The revised area of sympatry for Cultural Horizon A (Fig. 13) contains all 8 ILR taxa (north of broken line, 15 of 15 all mammals; 37 MNI; 1 MNI *C. ?familiaris* excluded) and is harmonious (Falk, 1981; Semken, 1981). It includes the Rainbow site and broadly indicates paleoclimatic similarity to the central plains and prairie states. This lack of specificity is caused both by the wide-ranging distributions of the mammals in the horizon A faunule and the small number of micromammal taxa, which generally have more restricted distributions than megamammals. The small sample of ILR taxa makes analysis by centers of distribution unreliable but steppe forms seem to dominate (Table 4). The undoubted strong cultural bias documented above prevents meaningful analysis of MNI percentages. However, Falk (1981) used the habitat preferences of all vertebrate classes (MNI basis) and records 24% stream, 9% riparian, 20% forest edge, and 31% grassland ecotypes present during the Sub-Atlantic portion of the occupation. Falk (1981) further suggested that the summary data indicate that forest and forest-edge species increased in the Scandic through Cultural Horizon B (circa 1,445 YBP) into Cultural Horizon C (1,410 - 1,350 YBP) and that there was a corresponding decrease in prairie ecotypes over this period. This trend agrees with the prediction of Benn (1981e) that woodlands progressively increased during occupation. It also supports the inferences of both Benn (1981e) and Baerreis (1981) that the Sub-Atlantic climate of western Iowa was more mesic than either that at present or that of the preceding Sub-Boreal climatic episode.

"Scandic" (1,680 - 1,260 YBP) — Four sites representative of the





Figs. 13-14. Areas of mammalian sympatry of 2 faunules from the Rainbow l.f., 13PM91, Plymouth Co., Ia.

Fig. 13. The 1,760 - 1,695 YBP Cultural Horizon A faunule: 8 of 8 ILR taxa (15 of 15 wild mammals to north of broken line) presently co-occur in the hachured area.

Fig. 14. The 1,410 - 1,350 YBP Cultural Horizon C faunule: 9 of 9 ILR taxa (19 of 19 wild mammals to west of broken line) presently co-occur in each hachured area.

Scandic episode have sufficiently diverse mammalian faunas for climatic interpretation. Three of these are archeological sites - the Rainbow (Fig. 1, 8) and M.A.D. (Fig. 1, 11; discussed above) sites where the records continue into the Scandic from the preceding Sub-Atlantic episode; and the Arthur site, Dickinson Co. (Fig. 1, 1). One is a non-cultural site - the Pleasant Ridge 1.b., Mills Co. (Fig. 1, 19).

At the Rainbow site, 13PM91, Mullenix Member alluvium (De Forest Fm.) continued to be deposited during Scandic time (Bettis and Thompson, 1982a). This alluvium contained Cultural Horizon C which has yielded 75% (185 MNI) of the Rainbow l.f. and was occupied circa 1,410 - 1,350 YBP (Benn, 1981c; Falk, 1981; Semken, 1981). Cultural Horizon C also contained 81% of the total MNI of the ILR taxa, 165 individuals represented by 8 rodent and 1 lagomorph species, counted from the site. Therefore, horizon C provides the best faunule for interpretation. Like the Rainbow A faunule, the low micromammal diversity in the Rainbow C faunule is probably due in part to the lack of bulk waterscreening and it weakens the paleoenvironmental analysis for this site. Furthermore, the Rainbow C faunule is dominated by *G. bursarius*, which represents 80% of the ILR individuals. Thus, like Cultural Horizon A, aboriginal subsistence practices introduced a strong cultural bias to the sample (Semken, 1981).

The area of sympatry (Fig. 14) constructed for Cultural Horizon C contains all 9 ILR taxa but is geographically too large to permit detailed climatic interpretations. However, it does suggest that Scandic climatic conditions can be related to some aspect of the broad ecotone which presently separates the eastern deciduous forest from the prairie of the Geat Plains. When all mammals are used (19 taxa, 183 MNI; 2 MNI *C. ?familiaris* excluded), *Vulpes velox* (Say), swift fox, restricts the area of complete overlap to west of the broken line. This suggests greater prairie affinities for the assemblage. Because of the few ILR taxa and the strong cultural bias, analysis of centers of distribution probably is unreliable, but it also suggests strong steppe influence in the paleobiota (Table 4). The Rainbow C faunule includes: prairie species - *S. franklinii, S. tridecemlineatus,* and *G. bursarius*; deciduous forest species - *S. niger* and *Peromyscus leucopus* (Rafinesque), white-footed mouse; and damp ground species - *S. cooperi* (Semken, 1981). Bowles (1975:97) notes that there is only one valid modern record for *S. cooperi* in northwest Iowa. *Synaptomys* thus is rare northwest of Des Moines and its presence in this small sample supports the prediction that relatively mesic conditions were present during the Scandic occupation of the Rainbow site.

More mesic conditions have been interpreted for Cultural Horizon C over those associated with Cultural Horizon A. Falk's (1981) analysis of the preferred habitats of all vertebrates records an increase of individuals representative of the forest/forest-edge community from 20% in Cultural Horizon A to 35% in Cultural Horizon C and a reciprocal decrease of grassland ecotypes from 31% to 20 percent. Although riparian taxa remained essentially constant, representatives of the permanent stream community dropped from 24% to 15%, and widespread species increased from 16% to 21 percent. *Odocoileus* sp., New World deer, were more abundant during the Scandic horizon C occupation than during the Sub-Atlantic horizon A.

The combined Rainbow C faunule would most likely be found today in a tall-grass/parkland situation, the prime habitat for *Odocoileus* and *S. niger.* The Rainbow C faunule implies that conditions in northwest Iowa were more moist in the Scandic circa 1,400 YBP than during the preceding Sub-Atlantic or the later Pacific climatic episode (see below).

The Pleasant Ridge l.f. (Fig. 1, 19) is non-cultural and was collected as two stratigraphic faunules from Mullenix Member alluvium (De Forest Fm.; Bettis and Thompson, 1982b) along Waubonsie Creek approximately 100 m downstream from the Sub-Boreal Garrett Farm l.f. in Mills Co. (Fay, 1978b). The two faunules were recovered from sandy gravel lenses separated by 0.5 m of silty alluvium (untested for faunal content). Charcoal fragments from the upper unit (PR-1) have been radiocarbon dated at 1,450 ± 90 RCYBP (DIC-1620; Fay, 1980). Both horizons were bulk-sampled and waterscreened on 1.6 mm screen for micromammals; the upper

yielded the majority of the fauna (61 of 67 MNI, all mammals). Twenty-three of the 24 taxa (excepting only *M. pinetorum*) were recovered from the upper horizon. Because of this faunal similarity and their close stratigraphic association, these two faunules were interpreted together by Fay (1980) and are combined in the analysis below.

Subdivision of the 19 ILR taxa (62 MNI; Table 2) in the Pleasant Ridge l.f. by centers of distribution, reveals that 33% are steppe, 33% deciduous forest, and 11% widespread forms (Table 4; adjusted from Fay, 1980). The remaining 22% are boreomontane. Comparison with the modern presettlement frequencies (Table 4) suggests that Scandic time was less mesic than that of southwestern Iowa today. When evaluated with respect to species composition (Table 4) in the Sub-Boreal Garrett Farm l.f., it appears that conditions were only slightly less mesic in Sub-Boreal than in Scandic time. Nonetheless, the Scandic climate of southwestern Iowa still was less conducive to tree growth (less mesic) than that of today. When the percent representation by individuals is considered (Table 4), the representation of forest (37%) and steppe (42%) individuals suggests slightly less forest cover than that inferred from the species percentages. Boreomontane forms also markedly declined (27% MNI in the Sub-Boreal Garrett Farm to 17% MNI in the Scandic Pleasant Ridge) implying warmer summer temperatures. This parallels the trend inferred from the Rainbow mammals which also indicates increasing effective precipitation from Sub-Atlantic to Scandic climatic episodes. However, because of low mammalian diversity at Rainbow, probably resulting from collecting strategy, the centers of distribution data cannot be reliably compared to those of the Pleasant Ridge local fauna.

The area of sympatry (Fig. 15) for the Pleasant Ridge l.f. lies to the southwest in northeastern Kansas. This tightly limited area contains all 19 ILR taxa and all 24 mammals (67 MNI); the local fauna thus is harmonious. Significantly, the large northern plains phenon of *Blarina (B. b. brevicauda)* is the only *Blarina* found in the Pleasant Ridge l.f. (Fay, 1980). Fay's (1980) diagnosis, using Graham and Semken's (1976) mandibular criteria is supported by Jones et al. (1984) study of the dental characters of the same specimens. If *Neotoma floridana* (Ord), eastern woodrat, is present only because of the exposure of suitable nest sites, then it can be excluded from consideration and the area of sympatry is larger (Fig. 15) but the interpretation is identical. This sympatry supports the supposition that Scandic time was more arid than modern middle Missouri Valley climates but is nearly equivalent to that of the Garrett Farm l.f. and does not support the trend seen in the analysis of centers of distribution.

The Arthur site, 13DK27, Dickinson Co. (Fig. 1, 1) is a cultural site and appears to represent a seasonally occupied camp, which lacked structures but contained storage and refuse features (Tiffany, 1982b). It was found along the shore of East Lake Okoboji (Abbott and Tiffany, 1982; Abbott, 1982a). Because of the littoral depositional environment and slow sediment accumulation rate, the lithostratigraphy of this site is difficult to interpret and has not been correlated with that of the Loess Hills Region (Abbott, 1982b). Although cultural features were waterscreened on 1.6 mm screen, no systematic bulk-sampling was undertaken to enhance micromammal recovery (Abbott, 1982b; Semken, 1982).

The vertebrate fauna collected from the Arthur site (Semken, 1982) spans Paleo-Indian, Archaic, Woodland, and Oneota occupations (Tiffany, 1982a). However, because most of the Arthur site artifacts are ceramics of late Woodland traditions (1,350 - 1,050 YBP), the majority of the fauna probably can be attributed to this interval. For this reason the interpretations that follow are assigned to the Scandic climate episode, but they are tentative until ongoing analyses of cultural associations permit subdivision of the fauna. Quantitative methods, relative abundance, and comparisons to the other sites are not included at this time since misrepresentation is bound to occur.

Altogether, 18 mammalian taxa (48 MNI) were found at Arthur (Tables 2 and 3; Semken, 1982). If coeval, these represent a varied community which includes large and small grazers, large and small browsers, and carnivores. The preferred habitats of the taxa were also diverse (deciduous forest, meadow, steppe, and aquatic). The association suggests that a storied parkland environment surrounded Lake Okoboji (Semken, 1982; Semken and Falk, in press). The lowland nature of the parkland is confirmed by meadow ecotypes being more prevalent than prairie ecotypes of the dry upland. The resource base available to the occupants thus was quite varied.

The long span of time from Paleo-Indian to Oneota occupations inevitably means that choronologically disjunct taxa have been inappropriately combined in the faunal list. Since the analysis of sympatry is particularly sensitive to this type of error, plotting of that for the Arthur site is deferred until the vertebrate remains can be subdivided into faunules associated with each cultural component. *Antilocapra americana* (Ord), pronghorn, has been recovered at Arthur and probably reached its presettlement eastern limit in or to the west of Dickinson County. Two of the Arthur l.f. small mammals are not present in Dickinson Co. today, *M. pinetorum* and *C. gapperi;* both reflect more mesic and forested conditions than present in the modern lowland around Lake Okoboji.

The Scandic of northwestern Iowa appears, as predicted by Wendland (1978), to have been relatively mesic with respect to today. However, southwestern Iowa (as interpreted from the Pleasant Ridge l.f.) seems to have been less mesic than today (Fay, 1978b; 1980). These conflicting interpretations could be real, caused by regional differences in the timing and sense of Holocene climatic change, or they may be spurious, reflecting only the physical mixing of specimens (by natural processes) of species which never simultaneously occupied each site. Nonetheless, they suggest that the north to south increase in forest cover (Novacek et al., 1985) was less pronounced in Scandic time than today and that the controlling regional climatic gradient (available effective precipitation?) was reduced. Only excavation of additional sites can explicate the apparent conflict between northwestern and southwestern Iowa records.

"Neo-Atlantic" (1,260 - 850 YBP) and "Pacific" (850 - 400 YBP) — The Neo-Atlantic of the northern plains has been characterized as both more moist than subsequent episodes (Pacific and Neo-Boreal) and as the culmination of a warming trend which began during the preceding Scandic episode (Wendland, 1978). Earthlodge villages of semi-sedentary agriculturists appeared on the plains during the Neo-Atlantic and this event has been related to the predicted increase in effective precipitation (Lehmer, 1970).

Dates assigned to this episode are subject to confusion in the literature. The Scandic/Neo-Atlantic and Neo-Atlantic/Pacific boundaries initially were placed at 1,050-1,150 and 700 YBP respectively (Baerreis and Bryson, 1965). Subsequently, adjustments were made to these boundary dates both by their authors (Bryson and Wendland, 1967; Wendland and Bryson, 1974) and by others (e.g. Lehmer, 1970). Additional data, better dating techniques, and more sophisticated analyses (Wendland, 1978) now place the beginning of the Neo-Atlantic at 1,260 YBP and the end of the episode at 850 YBP. Since inconsistent conversion of radiocarbon to calendar years ("corrected" dates) by various authors has contributed to the problem, dates in this paper are given in uncorrected radiocarbon years.

Only one non-cultural site of Neo-Atlantic age is available from the Loess Hills Region, the Thurman l.f. (Fig. 1, 20). Many, literally hundreds, of archeological sites of Neo-Atlantic and early Pacific age are known from the region, but fewer than 40 have any appreciable literature available. Adequate faunal analyses (particularly waterscreening for micromammals) are available from only 18 of these cultural localities and we restrict our discussion to 8 of them.

Turning first to a series of archeological sites in northwestern Iowa, the Great Oasis culture (Sioux variant) is represented by a faunule

from House 3 at the Broken Kettle West village site, 13PM25, Plymouth Co. (Fig. 1, 9; Baerreis, 1970a). Although associated with terrace alluvium of Broken Kettle Creek (D. Henning and E. Henning, 1982), lithostratigraphic correlation to the De Forest Fm. is not possible because detailed excavation reports are not available. The Great Oasis people were semi-sedentary agriculturalists who also exploited a wide variety of animals and plants (Anderson, 1975:33-41; E. Henning and D. Henning, 1982). They lived in open villages of wattle and daub walled, thatch-roofed, pit houses (Anderson, 1975:33-41). Of approximately 25 lodges at Broken Kettle West, 4 have been partly or wholly excavated (D. Henning and E. Henning, 1982) but a sketchy faunal report is available only for House 3 (Baerreis, 1970b). These faunal remains were recovered by D. Henning using a "waterscreening" technique (for features only?) on a "fine screen" (Baerreis, 1970b). House 3 radiocarbon dates (6 on charcoal) range from 1,100 to 880 YBP and suggest this lodge was occupied in the latter half of the Neo-Atlantic (Bender et al., 1973a).

House 3 at Broken Kettle West provided a mammalian sample of "90" MNI (Staab, 1970; Alex, 1970). Because this figure is calculated on a per feature basis and then totaled, the MNI's for the house undoubtedly are overestimated, particularly those for large mammals. The absence of tables of raw data prevented standardization with the other discussed sites. Altogether 15 taxa of mammals (Tables 2 and 3) were recovered (Staab, 1970; Alex, 1970) and all should have been found living in the vicinity of the site at the time of European settlement.

The artiodactyl sample from House 3 was dominated by *Odocoileus* ("37" MNI) with only 1 MNI *Bison* and "3" MNI *Cervus elaphus* Linnaeus, wapiti (= American elk) recovered (Staab, 1970). Strong dominance by *Odocoileus* may have been caused by: 1) local game availability (the site was probably in a gallery forest habitat), 2) cultural factors (e.g. dietary preference or seasonal occupation of the site), or 3) the climatically-determined ratio of game species present within the region. Fifty-seven percent of the 9 identified ILR taxa ("44" MNI; Alex, 1970) have centers of distribution in the steppe, prime *Bison* range. The paucity of *Bison* remains thus is probably not caused by macroclimatic conditions but rather is best explained by either local availability or cultural bias. The vertebrate remains from Broken Kettle West, including both mammals and non-mammals, do indicate that the resource base was sufficiently diverse between 1,100 and 880 YBP to support year-round occupation. Baerreis (1970a) demonstrates fall, winter, and spring occupation by analysis of various indicators of seasonality. In the absence of more complete reports, further interpretation is not here attempted.

Archeological sites of the Mill Creek culture (Initial Middle Missouri variant) have provided the 4 following Neo-Atlantic/Pacific faunal samples. These sites tend to be small, compact habitation areas; perhaps even fortified villages. In them, aboriginal cultural practices have resulted in the accumulation of rich midden deposits (Tiffany, 1982c:4). Long-continued or multiple occupation and intense human disturbance of these deposits (Tiffany, 1982c; Anderson, 1985) makes interpretation of both stratigraphy and fauna difficult. The inhabitants subsisted largely on agricultural produce but supplemented their diet with a wide variety of large and small wild game (Dallman, 1983). Subsistence procurement and intense use of the nearby environment may produce a strong cultural bias in the recovered fauna and distort interpretations. The Mill Creek peoples lived in semi-subterranean, wattle and daub walled, earthen-roofed houses (Tiffany, 1982c:4). Thus bone is well preserved when a structure collapses or burns but stratification would have been disturbed and mixing taken place during construction.

The Chan-ya-ta site, 13BV1, (Fig. 1, 4) is a single component Mill Creek village in Buena Vista Co. which was occupied briefly, for perhaps 50 years, around 900 YBP (7 radiocarbon dates on charcoal, Tiffany, 1982c). Although not waterscreened in bulk, samples were selected systematically for flotation on 40 mesh screen (about 0.4 mm opening) and all potentially productive matrix was dry-sieved through ¼" (about 6.4 mm) screen (Wegner, 1979; Tiffany, 1982c:12-15; pers. comm., 1986). This site is on a nose-slope at the edge of a geomorphic upland and therefore cannot be related to the De Forest Formation.

Feature 6 (a house and contained smaller features; 1 charcoal radiocarbon date, 870 ± 55 RCYBP) provided a mammalian sample of 59 individuals representing 15 species (Tables 2 and 3; including 5 MNI *C. ?familiaris*). All were gopher-sized or larger and all also "are inhabitants of the area today or historically were reported from northwest Iowa. They represent a range of habitats that are in easy walking distance of the site today" (Tiffany, 1982c:fiche 222). Thus, the Neo-Atlantic climate of Buena Vista Co., was similar to that at present. Even though a comparable sampling strategy produced an adequate sample at the Rainbow site, only 7 ILR taxa (12 MNI; Table 2) were recovered from Chan-ya-ta Feature 6. The Feature 6 sympatry is harmonious and virtually identical to that of Rainbow Cultural Horizon A (Fig. 13). Despite good preservation (Tiffany, pers. com., 1986), both the low recovery rate of micromammal bone and the broad prairie-association of the fauna suggest that aboriginal exploitation may have severely altered the local environment. Because of this small sample size and apparently strong cultural bias, relative abundance data can not be meaningfully analyzed.

The kinds and frequencies of tree species identified from charcoal and pollen in Mill Creek sites, e.g. Chan-ya-ta, Wittrock, Phipps, and Kimball (Henning et al., 1968); and Brewster (Conrad and Koeppen, 1972; Dallman, 1983) suggest that the composition of timber stands was similar to those of today (Tiffany, 1982c). However, Tiffany (1982c) points out that the location of Mill Creek villages may have been controlled by the location of timber stands and that the duration of the occupation may reflect the size of the stand. Thus, it is possible that the gallery forest predicted for Chan-ya-ta may not have been as extensive as at present. Using all paleoenvironmental and subsistence data, Tiffany (1982c:84) concludes Chan-ya-ta, and other Mill Creek villages, were occupied year-round.

The Brewster site, 13CK15, Cherokee Co. (Fig. 1, 5) is located on a low, probably Holocene, terrace remnant along Mill Creek (site map in Dallman, 1983, compared to USGS Cherokee North Quadrangle, 7½′ topographic map). Tiffany's (1982c:89, Table 30) assignment of this site to an "upland" setting is incorrect in a strict geomorphic sense because the site is at least 30 m, vertically, below the surrounding geomorphic upland and within the well-defined valley of Mill Creek. No attempt has been made to relate this site to the De Forest Fm. alluvial lithostratigraphy. The intense occupation of this site formed a midden of cultural deposits which is about 2 m thick. Selected bulk samples of the Brewster cultural deposits were systematically waterscreened on 1.6 mm screen or finer mesh to recover paleoenvironmental data (Dallman, 1983:11).

The Brewster site dates between 1,025 and 750 YBP (15 radiocarbon dates on charcoal, Dallman, 1983:99), and is categorized as a multicomponent village by Tiffany (1982c). These dates have been interpreted to represent: 1) a nearly continuous 275 year-long occupation by Mill Creek people (Anderson, 1985), 2) an occupation of about 100 years-length but starting no earlier than 850 YBP (Dallman, 1983:58), or 3) two brief occupations centered on 985 and 908 YBP (Tiffany, 1982c:71-72). The combined faunal composition of Brewster is nonetheless similar to that at Chan-ya-ta. Species representative of gallery forest, prairie, marsh, and permanent water all were present. Including *C. ?familiaris* (16 MNI), 23 mammalian taxa were recovered (647 MNI summed from each 1 foot level; Tables 2 and 3), 138 individuals were deer-sized or larger (Dallman, 1983:121-127, Table 35).

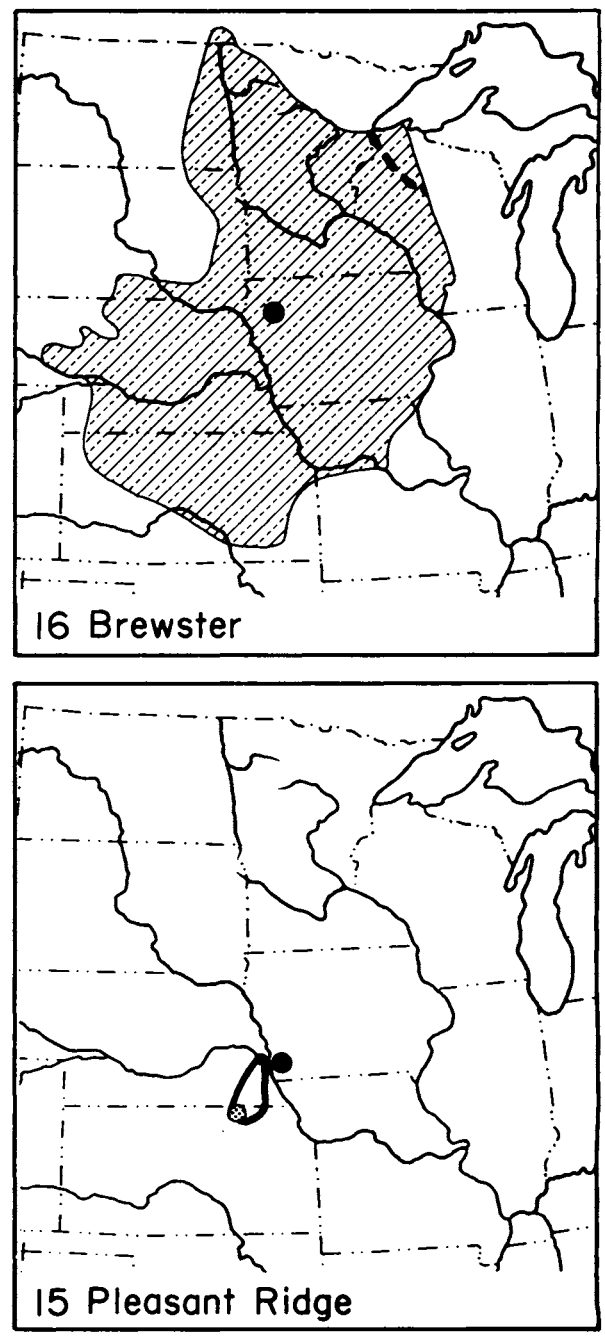
Geomys bursarius (333 MNI), is the most common mammal in the Brewster local fauna. This abundance, as in all other faunally analyzed

Mill Creek sites, presents a striking anomaly. *Geomys bursarius, S. tridecemlineatus* (54 MNI), and *S. franklinii* (22 MNI) can be serious pests in modern gardens (Chase et al., 1982; Tomich, 1982) and their strong presence in Brewster may suggest a similar problem in prehistoric times. These mammals could have been systematically harvested both for subsistence and in an attempt to mitigate their impact on garden plots (Benn, 1980:fiche 108). Because butcher marks were present on some individual *G. bursarius* elements, R. Alex (pers. comm. in Dallman, 1983:28) attributed this abundance to collection for the subsistence base. A similar *G. bursarius* concentration in the Rainbow site (Semken, 1982), Scandic in age and Woodland in cultural affiliation, also was interpreted as subsistence procurement. There was no evidence for marked change in either the species selected or the method of utilization of game during the occupation of Brewster. If the Neo-Atlantic/Pacific climate shift occurred during this interval, it did not have an impact on the recovered fauna.

The Brewster l.f. illustrated well the taphonomic characteristics of small mammal faunas which have been recovered from the occupation sites of semi-sedentary agriculturalists. Even though thoroughly waterscreened on fine-mesh screen, and despite yielding 461 MNI ILR taxa (46.1 MNI/taxon; still 128 MNI, 14.2 MNI/taxon, if the apparently harvested *G. bursarius* is excluded), it contains only 10 ILR taxa. Compare this paucity to the diversity at the 3 non-cultural Holocene local faunas: Garrett Farm - 17 ILR taxa, 58 MNI, 3.4 MNI/taxon; Pleasant Ridge - 19 taxa, 62 MNI, 3.3 MNI/taxon; and Thurman - 12 taxa, 29 MNI, 2.4 MNI/taxon. Furthermore, even when of similar species diversity, the cultural local faunas often have markedly larger areas of sympatry than do the non-cultural local faunas. At least two different models (not necessarily mutually exclusive) could explain these contrasts. (1) The small mammals were being selectively procured from the surrounding natural biota for culturally determined dietary reasons. (2) The environmental impact of native horicultural practices and settlement density was great enough to stress the local ecosystem and produce a concomitantly depauperate small mammal fauna. A choice between the two hypotheses is impossible in the absence of an extensive series of non-cultural micromammal sites in the immediate vicinity of any well-analyzed archeological faunas.

As a probable consequence of the low micromammal diversity (*vis-à-vis* non-cultural local faunas) the Brewster l.f. has a rather broad, uninformative sympatry (Fig. 16) which is defined by 10 ILR taxa (461 MNI). The site is at its center and contains all 22 wild mammals in the slightly smaller area to the southwest of the limit of *Bison bison* (Linnaeus), American buffalo (broken line). It covers most of the central plains and Upper Midwest. The 7 ILR taxa, assignable to centers of distribution, are 43% of steppe origin (Table 4). Although waterscreened in part, percent abundance on an MNI basis has not been examined at Brewster because readily apparent subsistence activities (e.g. *G. bursarius* butchering and perhaps consumption of *Spermophilus* spp. as well), has seriously biased the recovered fauna.

The Phipps site, 13CK21, Cherokee Co. (Fig. 1, 5) also is located along Mill Creek but on a surface close to or at modern floodplain level (Tiffany, 1982c:89, Table 30). Here the intensely-occupied village midden is over 3 m thick and radiocarbon dating of charcoal is interpreted to indicate a longer occupation than at the two preceding Mill Creek middens (Dallman, 1983:49). Again, no attempt has been made to relate the cultural deposits to the De Forest Fm. alluvial lithostratigraphy. Excavations from two major projects have been separately reported for the Phipps site: a University of Iowa/Sanford Museum project, directed by R. J. Ruppé, in 1955 (Dallman, 1983) and a University of Wisconsin project, directed by D.R. Henning and A.E. Henning, in 1963 (Henning, 1968; 1969). Dallman's faunal list (1983:121-127, Table 35) is based entirely on material recovered during Ruppé's 1955 excavation (Dallman, 1983:4; Tiffany, pers. comm., 1986) during which "all midden material" (Ives, 1962:6) was wet-sieved, but only on 6.4 mm screen (Ives, 1962:6; Henning et al., 1968:72). Correlation of the interpretations from each project is possible but integration is nearly impossible and has not been attemped by us or anyone.



Figs. 15-16. Areas of mammalian sympatry.

Fig. 15. The circa 1,450 YBP Pleasant Ridge l.f., Mills Co., Ia.: 19 of 19 ILR taxa (24 of 24 mammals) presently co-occur in the stippled area. If *Neotoma floridana* is excluded 18 of 18 ILR taxa co-occur in the outlined area.

Fig. 16. The 1,025 - 750 YBP Brewster l.f., 13CK15, Cherokee Co., Ia.: 10 of 10 ILR taxa (22 of 22 wild mammals to southwest of broken line) presently co-occur in the hachured area.

The Phipps site is a complex, multicomponent village (Tiffany, 1982c) which may have been occupied for over 400 years between 1,140 and 600 YBP (8 radiocarbon dates on charcoal, Dallman, 1983:99). It is one of the primary sites from which the boundary between Neo-Atlantic and Pacific climatic episodes was first defined in North America (Bryson and Wendland, 1967:294). Here, using changes in the relative abundance of pollen (James and Nichols, 1969), gastropods (Baerreis, 1969), and large ruminants (Frankforter, 1969); Bryson and Baerris (1968:29) noted that the separate data fields "confirm the reality of the climatic changes occurring synchronously with those of Europe during the Pacific episode" and added that these changes clearly had impact on culture.

A count and percentage tabulaton of identifiable *Odocoileus, Cervus,* and *Bison* elements (Frankforter, 1969:289-290, Tables 6:1 and 6:2) from each one foot level in the Phipps site (1963 University of Wisconsin excavation) recorded a progressive decrease in relative abundance of both *Odocoileus* and *Cervus* with a corresponding increase in the amount of *Bison* present over this period. *Odocoileus* comprised 65% of the identified elements in the lowest excavated level and 36% of the artiodactyl sample in the uppermost level. *Cervus* decreased from 23% to 0% of the sample over the same interval. Conversely, over this period *Bison* bone increased from 12% to 64% of the identified elements (Fig. 17). This change, while gradual, was accelerated between 850 and 750 YBP (dates interpreted by Frankforter, 1969, from a jumbled radiocarbon record). Dallman (1983) believes that his analysis of Ruppé's sample (1955 excavation) confirms this trend. However, the element percentage of *Bison* (1955 excavation) never falls below 48% in the 9 uppermost one foot levels (Fig. 17). Levels 10 and 11 (1955 excavation) each contained only 1 identifiable artiodactyl element.

Frankforter (1969) attributed the increase in frequency of *Bison* in the upper levels to climatic change, primarily because the associated pollen and gastropod data strongly supported such a change. An increase in the number of *S. tridecemlineatus* in the middle levels of the Phipps site supports Frankforter's (1969) interpretation but this may be only paralleling the overall bone frequencies (Dallman, 1983). Dallman (1983:50) also suggests that the upward increase in *Bison* could reflect only a concentration of hunting effort on the prey species which yielded more recoverable meat per kill and not climatic change. Nonetheless, if woodland habitat was giving ground to an expanding prairie, it did not entirely disappear because remains of *Urocyon cinereoargenteus* (Schreber), grey fox; *Odocoileus* sp.; *Mustela vison* Schreber, mink; and *Procyon lotor* (Linnaeus), raccoon, were found in the upper levels (Dallman, 1983).

Dallman (1983:121-127, Table 35), including 20 MNI *C. ?familiaris,* reports that Ruppé's excavation at the Phipps site yielded 30 mammalian taxa (738 MNI on a per level basis; including level 11 with 1 MNI each *Bison* and unidentified rodent which was excluded by Dallman, 1983). Although not waterscreened on fine mesh, the relatively high number of ILR taxa (15) for an archeological site implies fairly complete sampling. The phenomenal numbers of *G. bursarius* (275 MNI), *S. tridecemlineatus* (78 MNI), and *S. franklinii* (72 MNI) again suggest harvesting linked to subsistence procurement. The sympatry (Fig. 18) of the combined Phipps l.f. (all 15 ILR taxa, 515 MNI) is defined by taxa found exclusively in levels 3 through 6 (Pacific in age by Dallman's 1983:51-53, 60, correlation) and is to the east and south of the site. If Bowles' (1975) records are used for the modern county faunal list, then all ILR taxa (including *T. striatus,* excluded by Hall's, 1981, ranges) presently occur in Cherokee County. When all 29 wild mammals are included, the sympatry is limited to the area within the range of *Martes americana* (Turton), pine martin, northeast of the broken line. The mammalian sympatry, unlike the interpretation from the other data fields, thus suggests more mesic Pacific conditions than those of today. If *M. americana* is excluded for reason of its potential as a trade time (Purdue and Styles, in press) then the larger area (constrained only by small mammal

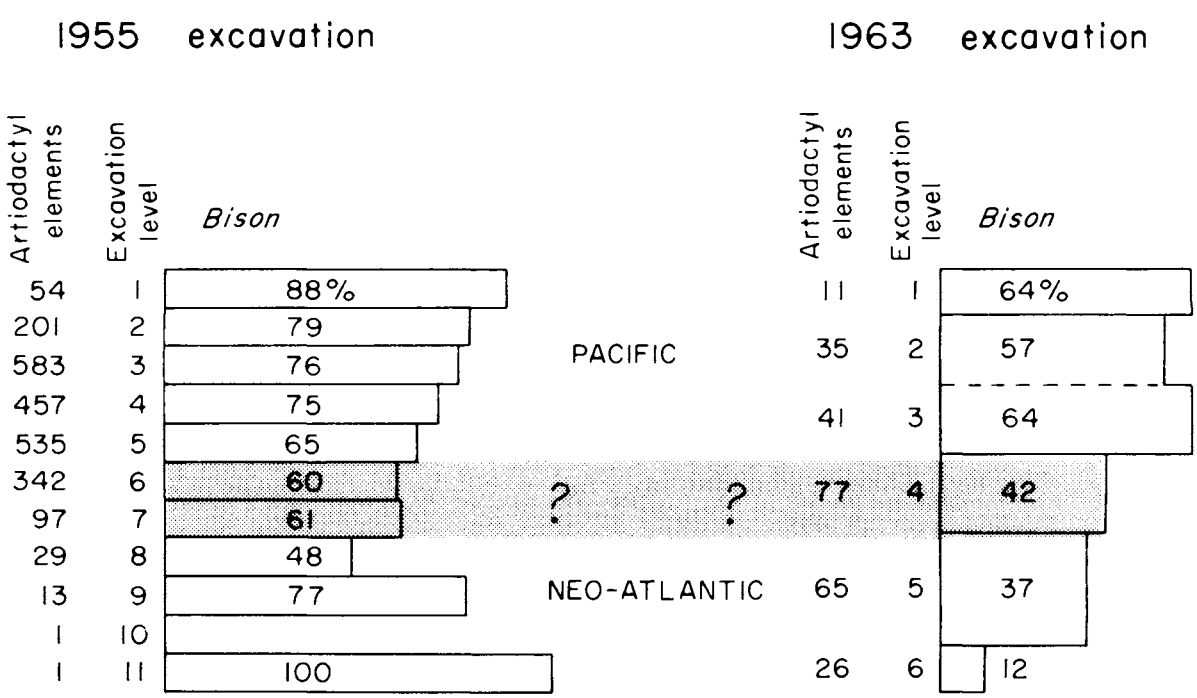


Fig. 17. Relative abundance of *Bison* bone per level in two excavations at the Phipps site, 13CK21, Cherokee Co., Ia. *Bison* abundance is expressed as a percent of all identified artiodactyl elements (*Bison*/*Bison* + *Cervus* + *Odocoileus* times 100). 1955 excavation from Dallman, 1983; 1963 excavation from Frankforter, 1969; approximate correlation of excavation levels inferred from Dallman, 1983:52, Fig. 14.

distributions) still indicates somewhat more mesic conditions. When the ILR taxa (MNI basis not used because of strong cultural bias) are categorized by centers of distribution, 50% are deciduous forest forms and none are boreomontane (Table 4). The centers of distribution analysis also supports the interpretation that the Pacific climate was more mesic than that of modern Cherokee Co. (Table 4), but the method may be unreliable.

The Wittrock site, 13OB4, O'Brien Co. (Fig. 1, 3) is a Mill Creek village located along Waterman Creek and is categorized as a "floodplain," multicomponent site by Tiffany (1982c:89, Table 30). Three excavations have been made at the Wittrock site: the University of Iowa 1959 project (Ruppé, 1959) virtually lacks a published record; the University of Wisconsin 1963 excavation (Henning et al., 1968), despite mentioning the recover of 290 ILR elements only reports the ruminants (Frankforter, 1969); and the University of Iowa 1965 project (directed by M. Mckusick; Semken, 1971) produced only a list of the small mammal remains plus incidentally included large mammals (Semken, 1971). Seven radiocarbon dates (charcoal; 3 on bone excluded) indicate that the site may have been occupied from about 980 to 525 YBP (Tiffany, 1981). The lithostratigraphy has not been related to De Forest Fm. members. Although the site was not waterscreened, Semken (1971) describes a small fauna (13 taxa, 33 MNI; 6 ILR taxa, 23 MNI) which is consistent with those found at the three other Mill Creek villages. Frankforter (1969) adds *Cervus* to the faunal list. Conforming to the pattern, almost 50% of the Wittrock mammals are *G. bursarius.*

Fifteen Neo-Atlantic/Pacific faunas are available from southwestern Iowa, 14 archeological and 1 non-cultural. The Thurman l.f. (Fig. 1, 20) is non-cultural and was taken from stratified sand and silt in the Fremont County Quarry, Fremont Co. (Jenkins, 1972). At the time of excavation this local fauna was regarded as late Pleistocene for two reasons: 1) sands in the micromammal-bearing section were correlated with proboscidean-bearing (thus "Pleistocene") sands elsewhere in the quarry and 2) the fauna contained extirpated micromammal species (not then believed possible in a Holocene local fauna). Subsequently, a radiocarbon date of 970±150 RCYBP (charcoal; I-6392) was obtained from the micromammal-bearing unit. This date is now accepted because Holocene local faunas, containing extirpated micromammals, have been well documented elsewhere (Semken, 1983). The alluvium at this site has not been assigned to any member of the De Forest Formation.

The Thurman l.f. (also known as "Fremont" l.f.) was recovered by systematic excavation and bulk-waterscreening on 1.6 mm screen for micromammals. It contains 14 distinct mammalian taxa (31 MNI; Jenkins, 1972). The 12 ILR taxa, when categorized by centers of distribution, are 20% each steppe and boreomontane forms and 60% deciduous forest (Table 4). When compared to the presettlement representation (Table 4), forested conditions seem to have been more widespread at the time of deposition of the fauna. Nonetheless, when relative abundance is recalculated on an MNI basis, taxa with a steppe center of distribution actually represent the most common individuals (steppe - 43% MNI, deciduous forest - 33% MNI, and boreomontane - 24% MNI). Furthermore, when the actual habitat preferences of the taxa are examined, those now living in meadow, grassland, or other open-ground habitats contribute over half the individuals to the Thurman local fauna.

The area of sympatry (replotted from Jenkins, 1972) for the Thurman l.f. (all 12 ILR taxa; 29 MNI) is located in northeastern Kansas (Fig. 19) and demonstrates that the Thurman is harmonious (all 14 mammals co-occur). This is also the location of the sympatries of the Sub-Boreal Garrett Farm and Scandic Pleasant Ridge local faunas. If *Neotoma,* the only taxon not in Fremont Co. today (but perhaps only eliminated from southwestern Iowa by alluviation over suitable home sites in rocky bluffs), is excluded, than all 13 taxa co-occur in a broad band outlined in Fig. 19 that extends eastward across southern Iowa and northern Missouri. Two *Blarina* phena are reported by Jenkins (1972) from the Thurman, *B. b. brevicauda* and *B. b. "carolinensis"* of Graham and Semken (1976). Jones et al. (1984), using a different suite of measurements on the same specimens, confirm the occurrence of *B. b. brevicauda* but refer the smaller elements to the semispecies *B. b. talpoides* rather than *B. hylophaga* (equals western *B. "carolinensis"* populations). Regardless of the correct diagnosis, all three phena presently co-occur, and in part define, the Thurman l.f. area of sympatry. The Neo-Atlantic climate of 970 YBP therefore appears to have been rather like that of the present in southwestern Iowa or slightly less mesic (if the sympatry with *Neotoma* is used). Because of the small sample size in the Thurman l.f., the absence of taxa better adapted to xeric conditions (e.g. *O. leucogaster* and *P. flavescens,* recorded in the Sub-Boreal Garrett Farm and Scandic Pleasant Ridge l.f.) probably is not significant. This absence therefore should not be used as evidence for increased moisture (more mesic conditions).

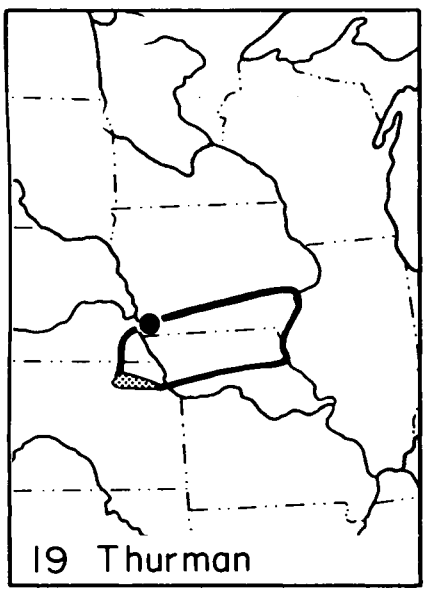
Reports on the mammalian remains are available from 14 archeological excavations at Glenwood occupation sites in southwestern Iowa. This "Glenwood local fauna" is broadly contemporaneous with the Mill Creek culture local faunas discussed above. The Glenwood people, semi-sedentary agriculturists of the Central Plains Tradition (Nebraska phase) and earthlodge builders, entered southwestern Iowa about 1,000 YBP and remained there until 700 YBP (42 radiocarbon dates on charcoal, Hotopp, 1978a; 1978b). This period transgresses the 850 YBP boundary between Neo-Atlantic/Pacific episodes. Over 30 Glenwood lodges, loosely associated in clusters, have been excavated and matrix from 14 of these (in the Pony, Keg, and Horse Creek watersheds of Mills Co.; Fig. 1, 18) has been either partially or totally waterscreened on 1.6 mm screen. Deep midden accumulation does not occur in Glenwood sites (Hotopp, 1978b). These sites occur in a variety of geomorphic positions from upland ridges to low terraces but their lithostratigraphy has not been related to the De Forest Fm. members. Johnson (1972) summarized the faunal remains recovered to that date and found two taxa which no longer occur in Mills County: *Oryzomys palustris,* now found only to the south, and *Onychomys leucogaster,* now found only to the west. *Onychomys leucogaster* also was recovered in the nearby Sub-Boreal Garrett Farm and the Scandic Pleasant Ridge local faunas. Semken (in Fulmer, 1974; Semken, 1983) later identified *C. gapperi* from a circa 735 YBP lodge. The latter lodge is on the floor of a deep valley in the loess bluffs which, during the Pacific episode, may have sheltered a relict population of this vole 300 km southwest of its present Midwestern range.

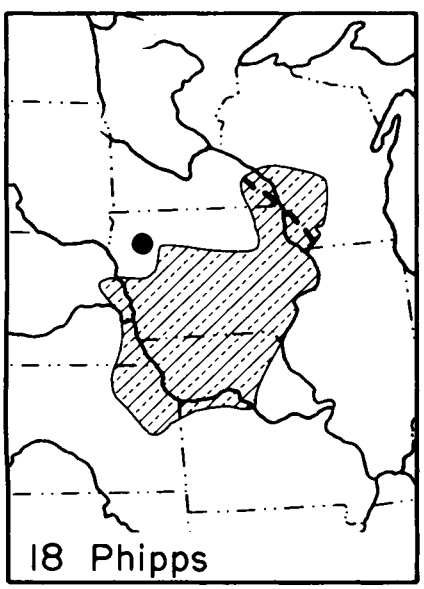
Conflicting climatic interpretations for the Glenwood sequence can be derived from these range extensions - warmer and more moist (*Oryzomys*), cooler and with more effective precipitation (*Clethrionomys*), or drier (*Onychomys*). Johnson (1972:16) grouped his samples by both physical proximity and geomorphic position ("ridge top, floodplain, and hill slope"). He demonstrated that the sample from the "ridge top" lodge had a more xeric composition than those from the "floodplain" (Johnson, 1972:53-59). Limited radiocarbon control prevented Johnson (1972) from evaluating chronoclimatic factors.

Additional excavations, larger samples, and 42 radiocarbon dates reported by Hotopp (1978a; 1978b) permitted Bardwell (1981) to partially test both the chronologic and geomorphic factors at Glenwood. She also evaluated all reported occurrences of *O. palustris* from north of its modern range and concluded that this taxon is present in the Glenwood l.f. for non-climatic reasons. *Oryzomys palustris* was most probably a commensal pest (as is the recently introduced *Rattus,* Old World rat) in the Glenwood lodges and populations lived in close association with the aboriginal inhabitants (Bardwell, 1981:32-38). This argument was based in part on the lack of *O. palustris* from non-cultural contexts outside its present range. The hypothesis is weakened by the scarcity of reported non-cultural localities resulting from lack of interest by paleontologists in excavation of late Holocene

sites. Satorius-Fox (1982:23-40), in her study of the Schmidt site, 25HW301, Howard Co., Nebraska, attributed the presence of large numbers of *O. palustris* there to an unresolvable combination of both climatic and commensal factors. Nevertheless, like *G. bursarius* in the Mill Creek sites, *O. palustris* may have been exploited as part of the Glenwood subsistence base (Bardwell, 1981).

Preliminary analysis of a non-cultural site of almost the same age from the nearby Waubonsie watershed (Chaboneau l.f.; 705±85 RCYBP [charcoal], I-7381; probably Turton Member, De Forest Fm.; Rhodes and Semken, 1976) disclosed no *Oryzomys* in a sample with more than 30 MNI; neither was it recovered in the non-cultural Thurman l.f., just slightly earlier than the Glenwood earthlodges, 20 km to the south (Jenkins, 1972). This is expected with Bardwell's hypothesis - if *O. palustris* were a commensal pest, then it should be rare or absent in non-cultural contexts. Unfortunately, no non-cultural site is known in the immediate vicinity of an earthlodge cluster for comparison. Therefore *Oryzomys*, because of this potential commensal association, is excluded from the following anaylsis.





Figs. 18-19. Areas of mammalian sympatry.

Fig. 18. The 1,140 - 600 YBP Phipps l.f., 13CK21, Cherokee Co., Ia.: 15 of 15 ILR taxa (29 of 29 wild mammals to northeast of broken line) presently co-occur in the hachured area.

Fig. 19. The circa 970 YBP Thurman l.f., Fremont Co., Ia.: 12 of 12 ILR taxa (14 of 14 mammals) presently co-occur in the stippled area. If *Neotoma* sp. is excluded 11 of 11 ILR taxa co-occur in the outlined area.

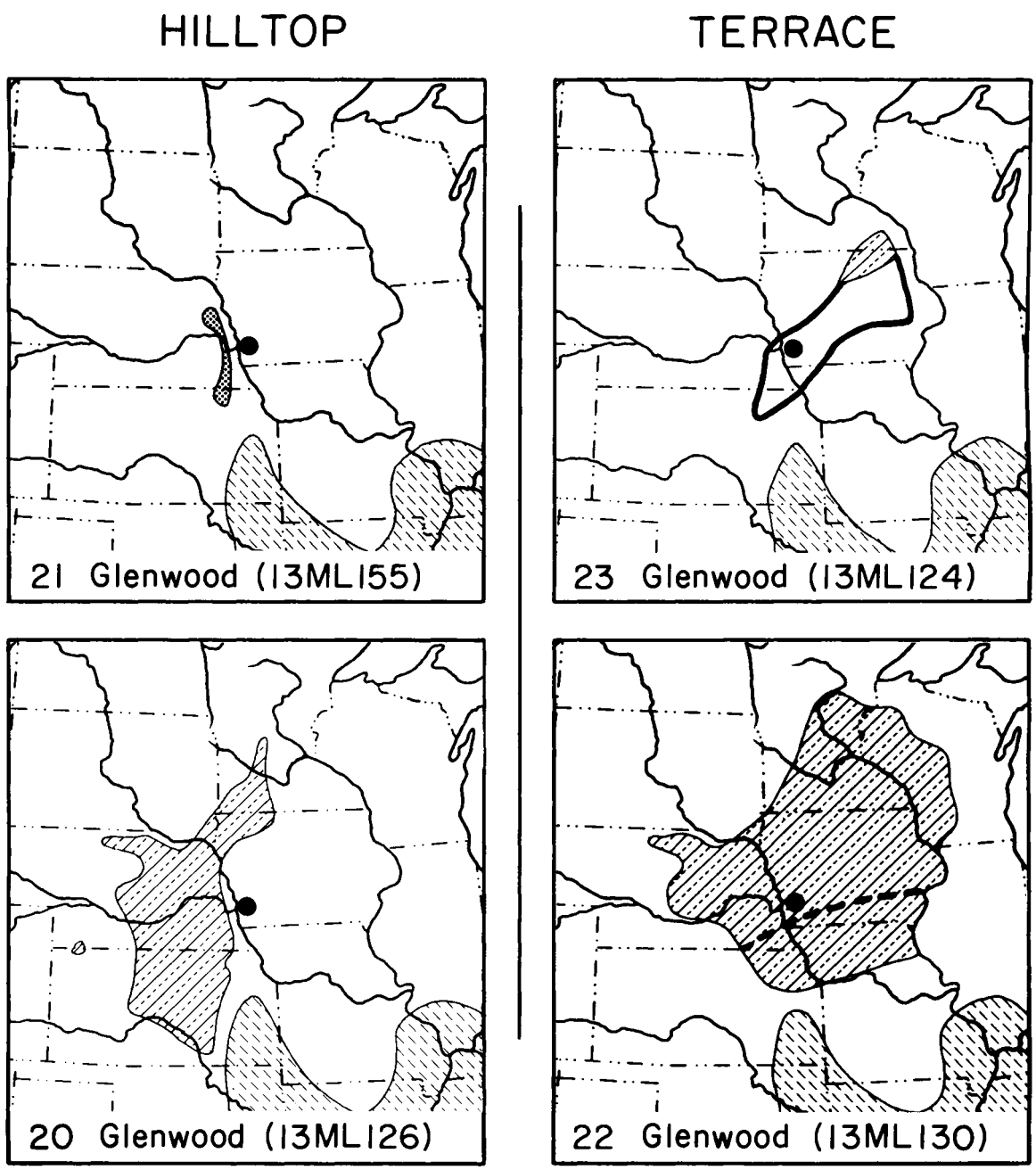
Using only the ILR taxa plus bats, Bardwell (1981:48-53) confirmed the bio-topographic zonation ("hilltop" vs. "terrace") reported by Johnson (1972) and demonstrated that it was most pronounced in the Glenwood region during the early part of the occupation period. A cool, damp environment, which supported both meadows and forests, was present on the floodplains; valley slopes were characterized by well-drained woodlands which graded upslope first into a shrubby zone and finally into an upland prairie. Because differences in geomorphic position clearly effected both the area of sympatry and relative abundance of species in each Glenwood faunule (lodge sample), Bardwell (1981) tested for temporal change by comparing early (852 YBP; 13ML126) to late (698 YBP; 13ML155) hilltop faunules and middle (807 YBP; 13ML130) to late (735 YBP; 13ML124) terrace faunules. These faunules (listed separately in Tables 2 and 3) were selected because their sample size was large compared to the other 10 sites; the 4 faunules also include all mammalian taxa reported from the 10 remaining sites. For our discussion, all sympatries have been adjusted to the standard set of range maps and the commensal (*O. palustris*) has been excluded; with this exclusion all 4 sympatries are harmonious. The study of the non-ILR taxa is not complete and these specimens are not addressed.

The 852 YBP hilltop faunule, strongly dominated by prairie species, has a large area of sympatry (all 12 ILR taxa; 26 MNI, excluding 21 MNI *O. palustris*) on the plains to the west of Mills Co. (Fig. 20). All 16 mammals reported by Johnson (1972; *M. pennsylvanicus* was misidentified and is here rejected) and Bardwell (1981), except the probable domestic *Canis* and commensal *Oryzomys*, occur in this sympatry. Despite the chance of disproportionate cultural bias, relative frequencies for centers of distribution have been calculated (both by taxon and MNI; *Oryzomys* excluded) for these Glenwood lodges (Table 4). This analysis confirms the presence of a prominent upland steppe component in the 852 YBP hilltop faunule.

The 698 YBP hilltop faunule is less strongly dominated by steppe species than the 852 YBP sample. It includes *M. pennsylvanicus; S. niger; Cryptotis parva* (Say), least shrew; and *T. striatus*. These species suggest that open forest had expanded onto the uplands toward the end of the Glenwood occupation. *Tamias striatus* limits the sympatry of the 698 YBP faunule to extreme eastern Nebraska and Kansas (Fig. 21; all 16 ILR taxa; 40 MNI, excluding 27 MNI *O. palustris*). An increase in taxa with centers of distribution in the deciduous forest (Table 4) corroborates this trend. This also implies that precipitation was more effective in early Pacific time than in the earlier, presumably more moist, Neo-Atlantic climatic episode.

Sympatries for both of the terrace faunules are more eastern in distribution than the hilltop faunules. Because the distributions of the two phena of *B. brevicauda* are not known in western Wisconsin and southeastern Minnesota (Jones et al., 1984), the sympatry of the 807 YBP terrace faunule (Fig. 22; all 10 ILR taxa; 25 MNI, excluding 21 MNI *O. palustris*) was constructed using the combined ranges of both *B. b. brevicauda* and *B. b. kirtlandi*. The sympatry could be further constrained by the known co-occurrence of these two phena in the smaller area to the south of the broken line (all 11 ILR taxa). Nonetheless, the sympatry indicates somewhat more mesic conditions than that for either hilltop faunule. The centers of distribution data (Table 4), when computed by relative frequencies of taxa, appear to support this conclusion but, on an MNI basis, the ratios are more nearly like the older hilltop faunule.

The sympatry of the 735 YBP terrace faunule (Fig. 23; all 16 ILR



Figs. 20-23. Areas of mammalian sympatry of 4 earthlodge faunules from the Glenwood l.f., Mills Co., Ia. *Oryzomys palustris* (now occuring to south in region hachured with broken lines) is excluded from all sympatries and counts.

Fig. 20. The circa 852 YBP hilltop faunule (13ML126): 12 of 12 ILR taxa (16 of 16 wild mammals) presently co-occur in both hachured areas to north.

Fig. 21. The circa 698 YBP hilltop faunule (13ML155): 16 of 16 ILR taxa (non-ILR not analyzed) presently co-occur in the stippled area.

Fig. 22. The circa 807 YBP terrace faunule (13ML130): 10 of 10 ILR taxa (non-ILR not analyzed) presently co-occur in the hachured area to north when the two semispecies of *Blarina brevicauda (B. b. brevicauda* and *B. b. talpoides)* are lumped. All 11 ILR taxa, including both *Blarina* semispecies, co-occur in the smaller area south of the broken line.

Fig. 23. The 735 YBP terrace faunule (13ML124): 16 of 16 ILR taxa (18 of 18 wild mammals) presently co-occur in the hachured area to north. If *C. gapperi* is excluded, 15 of 15 ILR taxa co-occur in the outlined area.

taxa; 30 MNI, excluding 5 MNI *O. palustris*) is restricted to the eastern Iowa/Minnesota border by the occurrence of *C. gapperi*. If this taxon was indeed a relict in sheltered Mills Co. microhabitats, then it may only indicate the presence of small areas with suitable microclimatic conditions, not the prevailing macroclimate. The outlined area indicates the sympatry without *C. gapperi* and includes the Glenwood locality. When the two terrace faunules are compared, the centers of distribution data (Table 4) indicate that steppe forms had increased (both taxa and MNI frequencies) by 735 YBP, mostly at the expense of widespread forms.

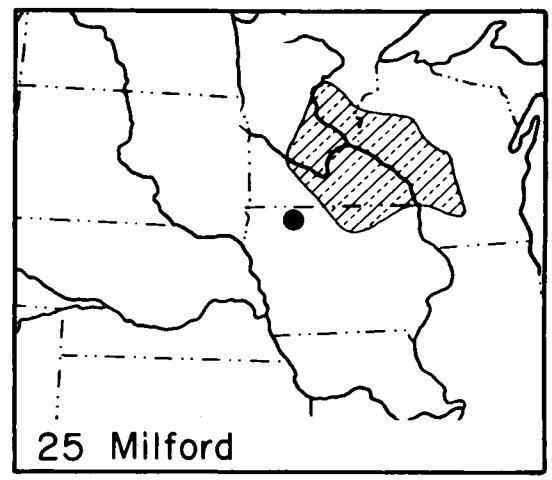
When the species lists for all 4 faunules are combined, the single best area of sympatry (Fig. 24) is on the eastern Kansas/Nebraska border to the southwest of Glenwood and it contains 20 of 21 taxa (195 MNI). The probable commensal *O. palustris* and the possible relict *C. gapperi* are absent from both this area and present-day Mills County. The only other species, recovered as a fossil, absent from the modern fauna of Mills Co. is the plains inhabitatnt, *O. leucogaster*.

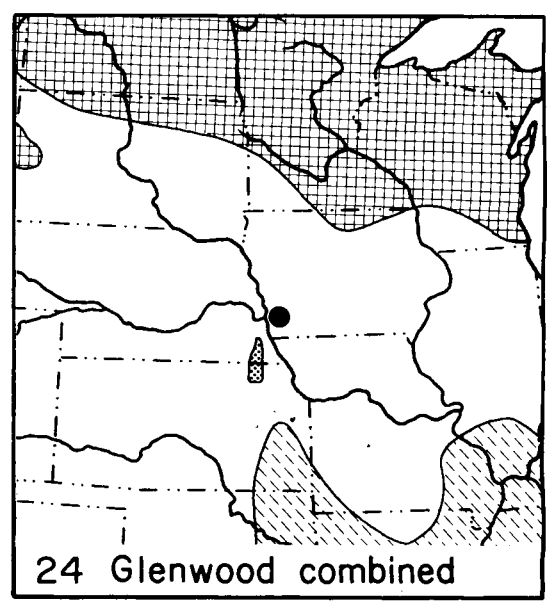
When habitat preference is considered, the relative abundance of forest forms in both hilltop and terrace faunules increases with decreasing age (Bardwell, 1981). This increase is primarily at the expense of wetland species and it suggests that the floodplain was becoming dryer (experiencing fewer floods) while precipitation was becoming more effective (forest expansion) on both the uplands and terraces. This paradoxical decrease in wetland taxa could be caused by a rapid gullying episode initiated prior to 705 YBP. Turton Member alluvium, De Forest Fm., is documented from the nearby Waubonsie watershed at that date (Rhodes and Semken, 1976; Bettis and Thompson, 1982b) and its deposition marks the termination of this gullying. Such entrenchment could have lowered water tables and drained local wetland habitats in seeming contradiction to other precipitation indicators. The hilltop and terrace associations exhibited similar proportions by about 750 YBP. Bio-topographic gradient thus was reduced to minimal contrast early in Pacific time. This reduction in environmental diversity may account for abandonment of the area by the Glenwood people (Bardwell, 1981).

"Neo-Boreal" (400 - 100 YBP) and "Recent" (100 YBP - Present) — Only one local fauna, either archeological or non-cultural, is available in western Iowa for these two youngest Holocene climatic episodes. Three concentrations of cultural material have been excavated at Milford site, 13DK1, Dickinson Co. (Fig. 1, 2; manuscript by Spargo, n.d.; on file SUI Paleontological Repository). Native American artificats are related to the Oneota cultural complex, but some early trade goods of European manufacture also are present. Although not radiometrically dated, this association of artifacts documents a circa 250 YBP proto-Historic age that places the site in the Neo-Boreal ("Little Ice Age"). The artifact concentrations are shallowly buried on the surface of an older terrace (also undated) of the Little Sioux River. All excavated material was sieved on 6.4 mm screen and microvertebrates were recovered by selective bulk-sampling and waterscreening on 1.6 mm screen. The combined mammalian fauna of the Milford site (primarily from the south and east concentrations) consists of 23 taxa (128 MNI; Tables 2 and 3) and includes both the probable domestic, *C. ?familiaris* (9 MNI), and the European-introduced commensal, *Rattus* (2 MNI).

The ILR sample of 14 taxa (70 MNI excluding *Rattus*), like many other archeological sites in northwestern Iowa, is dominated by *G. bursarius* (31 MNI; 44%). This strong representation probably is caused by cultural activities. The Milford site has a harmonious sympatry (14 ILR taxa; 21 of 21 all wild mammals) to the northeast of the site in Minnesota and Wisconsin (Fig. 25). This sympatry indicates only slightly cooler and perhaps more moist conditions than those of today. Such an interpretation is consistent with the climate inferred for the Neo-Boreal age that is derived from cultural associations. The centers of distribution data (Table 4; taxon basis only) shows a distinctly smaller deciduous forest component than that present in northwestern Iowa (14% vs. 33%) today and an increased representation of widespread forms. Boreomontane and steppe species have nearly identical proportions to those of today. *Clethrionomys gapperi* is the only taxon which does not now occur in the vicinity of the Milford site. Most of the non-ILR taxa appear to have been associated, at least seasonally, with gallery forest along the Little Sioux River (Spargo, n.d.).

No Historic sites have been excavated and faunally analyzed in the Loess Hills but mammalogists have recorded the effect on the fauna caused by changes in land use since invasion by Euroamerican peoples (Bowles, 1975). There have been dramatic changes in the distribution of large mammals; both before and after agricultural homesteading,





Figs. 24-25. Areas of mammalian sympatry.

Fig. 24. The combined 1,000 - 700 YBP Glenwood l.f., Mills Co. Ia.: excluding *O. palustris*, 20 of 21 ILR taxa (non-ILR taxa incompletely analyzed) presently co-occur in the stippled area. *Clethrionomys gapperi* occurs to north in cross-hatched regions; *O. palustris* to south in region hachured with broken lines.

Fig. 25. The circa 250 YBP Milford l.f., 13DK1, Dickinson Co., Ia.: excluding *Rattus norvegicus*, 14 of 14 ILR taxa (21 of 21 wild mammals) presently co-occur in the hachured area.

game and fur-bearers were efficiently hunted, and after sod-breaking, all were effected by severe habitat modification. These practices have eradicated wild populations of *E. dorsatum; Ursus americanus* Pallas, black bear; *Canis lupus* Linnaeus, grey wolf; *Felis concolor* Linnaeus, cougar; *Martes pennanti* (Erxleben), fisher; *Gulo gulo* (Linnaeus), wolverine; *L. canadensis; Odocoileus hemionus* (Rafinesque), mule deer; *C. elaphus; A. americana;* and *B. bison* from Iowa. Other species, including *Odocoileus virginianus* (Zimmermann), white-tailed deer, and *C. canadensis,* were pushed to the verge of local extinction. The impact on faunal distributions of the agricultural development of the Loess Hills is difficult to evaluate but it has been severe on large mammals and even micromammals have adjusted their ranges to the changing land use patterns (Bowles, 1975; Semken, 1983). Since the original mammal ranges at settlement (and today) are the foundation of our paleoenvironmental analysis, it is thus of the utmost importance to our interpretations that these distributional adjustments be recognized and that allowance be made for them.

CONCLUSIONS

The rich potential of the Loess Hills Region for research in vertebrate paleontology has scarcely been tapped. Indeed, the alluvial fills and archeological sites of the entire Middle Missouri Valley undoubtedly contain a fascinating and nearly complete fossil record for Wisconsinan and Holocene time. Only the beginning of this story can be cobbled together from the sites so far investigated. Occasional recovery of pre-Rancholabrean fossil mammals in the Loess Hills suggests that there is potential for the discovery of earlier Pleistocene faunas.

The so-called "Aftonian" fauna is not Aftonian in age as the name is presently (and probably inaccurately) used. Neither is it clearly correlative to the type Aftonian section as it was defined nearly 80 years ago near Afton Junction, Iowa. These classic "Aftonian" faunas were mis-evaluated and are either latest Irvingtonian or earliest Rancholabrean in age. Additional field work, particularly systematic excavation, is required to determine both the age and stratigraphic context of these predominantly turn of the century collections. Two micromammal-bearing horizons are currently under investigation at the radiometrically-dated Little Sioux locality of about the same age as the "Aftonian" fauna and indicate that the climate circa 740,000 YBP probably was both cooler and more moist than today's.

The mammalian record of the last 25,000 years in the Loess Hills contributes significantly to the reconstruction of the Late Quaternary climatology and zoogeography of the Upper Midwest. Most isolated finds of extinct megamammals like *Mammuthus* sp. and *Megalonyx jeffersonii* are undoubtedly of last glacial, Wisconsinan age. Although each of these megamammals probably had a distinct diet, most of the extinct taxa are grazers. Their environment can be reconstructed from 3 radiocarbon-dated micromammal sites of Wisconsinan age which have been examined in western Iowa. These contains the remains of taxa which are now both current residents of the Loess Hills and others living in more boreal environments to the north of Iowa. The Wisconsinan fauna best represents a mosaic of boreal hardwoods and conifers distributed in an open, meadow-like grassland or parkland during much of the glacial period. Forest density increased as the Wisconsinan came to an end. By late glacial time, closed spruce forest had enveloped much of the Upper Midwest; deciduous trees then invaded (around 12,500 YBP) and dominated the closed forest in western Iowa by about 11,000 YBP (Van Zant, 1979; Baker and Waln, 1985). It is clear, from this pollen analytical evidence, that there were large-scale, climatically-driven, changes in the composition of the biota around the Wisconsinan/Holocene transition (Van Zant, 1979; Baker and Waln, 1985). Although so far unrecorded in vertebrate-bearing sites of the Loess Hills, either climatic change or the hand of man caused extinction of the megafauna around 10,000 YBP.

The "interglacial" Holocene local faunas of the Loess Hills contrast to those of the Wisconsinan glacial by the disappearance of previously common species. Some taxa became extinct, others were locally extirpated and live to the north or northwest of Iowa today. There also was an overwhelming increase in the number of *Bison* which appears to have replaced the biomass of the more diverse Wisconsinan megafauna. Thus, the composition of the Holocene local faunas is depauperate with respect to the Wisconsinan and is similar to that found in western Iowa when Europeans first entered the state. The Holocene fauna has not been static but rather has shown changes in both distribution and relative abundance of species over the last 10,000 years. These changes probably are a response to climatic variation and have been interpreted here in that manner.

There are no early Holocene (10,000 - 8,490 YBP) local faunas known from the Loess Hills during the transition from glacial conditions, but, the oldest horizon of the Cherokee l.f., dated at 8,400 YBP, is only slightly younger. By this time grassland, probably nearly indistinguishable from modern prairie, had replaced the early Holocene deciduous forest and dominated the landscape as did the mid-glacial boreal grasslands. This interpretation is reinforced by the analyses at both the early Holocene (9,000 YBP) Dows l.f. in north central Iowa (Hudak, 1984) and the pollen analysis of Lake West Okoboji sediments (Dickinson Co., Iowa; Van Zant, 1979).

The Cherokee l.f. is the only middle Holocene (8,490 - 5,060 YBP) site known from the Loess Hills region. It has been divided into 3 faunules, dated at 8,400, 7,300, and 6,350 YBP; each was collected from one of the 18 paleosols identified in an alluvial fan. The presence of these multiple paleosols indicates episodic deposition followed by varying periods of quiescence in this interval; the longer periods of stability permitting greater soil development. The faunules thus represent "non-depositional" periods of the middle Holocene. Both the relative abundance of individuals and the areas of sympatry for each faunule suggest that the climate was slightly different than any in North America today and that northwestern Iowa experienced increasing aridity, ultimately severe. At about 8,400 YBP the Cultural Horizon III faunule indicates more mesic conditions than either those of today or the two succeeding faunules at Cherokee. It suggests that the early mid-Holocene of western Iowa was relatively moist. The number of steppe species progressively increased at the expense of woodland and boreomontane forms after this time. Each younger sympatry lies west of the earlier one, culminating in that for the 6,350 YBP horizon to the west of Cherokee. Thus, western Iowa was considerably more arid 6,350 YBP than at any time in recorded history. Sediments and paleobotanical remains from Lake West Okoboji (Van Zant, 1979; Baker and Van Zant, 1980) suggest that the period from 7,700 to 3,200 YBP was the most arid time in the Holocene of western Iowa and that lake level was 10 meters below that of today. The northern aspect of the sympatries indicate that summers were cooler. A cool, arid configuration is best explained by dominance in summer of Pacific air, which is both cool and dry, over the Loess Hills, late in the mid-Holocene. This period is known as the altithermal in other regions of the United States.

The late Holocene (5,060 YBP - present) generally was more mesic than the middle Holocene and markedly so with respect to the latter part of the mid-Holocene altithermal. During the Sub-Boreal (5,060 - 2,760 YBP), represented only by the Garrett Farm l.f. of southwestern Iowa, steppe species continued to dominate the fossil record but the number of forest species increased with respect to middle Holocene samples. Thus, gallery forests apparently expanded, but nonetheless, were not as extensive as today. This response may have resulted from warmer summers since there is evidence for less effective precipitation.

Sub-Atlantic climates (2,760 - 1,680 YBP) supported a well-developed riparian gallery forest imbedded in a tall-grass prairie. There were periodic droughts, especially early in the episode, but the

Sub-Atlantic probably became more mesic toward its end than either the preceding Sub-Boreal episode or the present. Steppe influence still was present in the Scandic (1,680 - 1,260 YBP) but relatively mesic and ecologically diverse conditions, in comparison to those of the Sub-Atlantic and today, were characteristic of northwestern Iowa. Although, forests increased during the Scandic in northwestern Iowa, this expansion apparently did not extend to southwestern Iowa where there is slight evidence for decreased moisture. Indeed, the vegetational gradient in the Loess Hills (presently hill slope and upland forest cover increases to the south; Novacek et al., 1985) may have been more subdued. Scandic climate definitely was warmer than that of the Sub-Atlantic. This factor may have differentially increased evaporation and produced more steppe-like conditions in southwestern Iowa.

During a still warmer Neo-Atlantic (1,260 - 850 YBP) steppe expanded on the uplands and timber stands either maintained modern proportions or expanded in the valleys. This created a stronger biozonation in the Loess Hills than at any other time in the Holocene. The resource base, available for aboriginal exploitation, correspondingly increased because of the edge effect. The lower boundary of the Pacific episode (850 - 100 YBP) was in part defined by a shift from deer to bison procurement at the Phipps site. This was regarded as indicative of grassland expansion in response to increased aridity. However, the small mammal data suggest that the Pacific climate was somewhat more mesic than that in the area today. An ecological change also is recorded to the south (Glenwood) but it is represented by expansion of the gallery forest onto the upland. This expansion was contemporaneous with a loss in the lowlands of both marsh and permanent water habitat. This paradox may result from decreased rainfall but greater effective precipitation. Either increased cloud cover or greater persistence of cool "Pacific" (fewer summer highs) air could achieve this composite result. Nevertheless, these southern Loess Hills sites all seem slightly less mesic than today. Taken together with the Mill Creek localities, they suggest, as in the Scandic, a more subdued north-south vegetational gradient than at present.

During the Neo-Boreal (400 - 100 YBP), represented by only the Milford site in northernmost western Iowa, climatic conditions were slightly cooler than those of either the Pacific or at present. The initial stage of Euroamerican impact on the fauna is visible during this episode; Milford records the earliest fossil record for Iowa of the introduced commensal pest, *Rattus*. Historical accounts of the "Recent" episode (100 YBP - present), document the settlement of Iowa and expansion of European agricultural practices. The presettlement megafauna, primarily plains herbivores, practically was exterminated and the natural ecosystem severely disturbed resulting in significant changes in the distributions of micromammals.

To fully illuminate the paleoclimatic record of the late Quaternary in the Loess Hills region, chronologic and geographic gaps must be filled. It also will be necessary to remedy methodological incompatibilities caused by the differing data recovery techniques employed in the various disciplines involved in these paleozoological studies. The understanding of the taphonomic differences between archeological and non-cultural faunas is of particular concern. At present it is clear that significant climatic changes, on a sub-regional scale, occurred in both magnitude and direction even within the relatively small area of the Loess Hills. The cooperation of amateur and professional archeologists, paleontologists, and mammalogists has both clearly defined the problems and provided a sound foundation for further study.

ACKNOWLEDGEMENTS

Lise Spargo (Milford site), Weldon D. Frankforter ("Aftonian" fauna), and David W. Benn (M.A.D. sites) kindly allowed us to use the preliminary reports on their research and excavations. The Office of the State Archaeologist (Iowa) provided invaluable assistance by providing access to project completion reports and reviewing the archeological contexts of this paper: we especially thank Duane C. Anderson, Joseph A. Tiffany, and Debby J. Zieglowsky of that office for their efforts on our behalf. We are grateful to the Illinois State Museum for furnishing completed drafts of the areas of sympatry (by Julianne Snider) and to Joyce E. Chrisinger for final drafting of all figures. We also are indebted to Carl R. Falk for his discussions with us about Plains zooarcheology, to Michael R. Voorhies, and to the reviewers of this lengthy manuscript.

REFERENCES

ABBOTT, L. R. 1982a. Environmental summary [of Arthur site], p. 7-14. *In* J. A. Tiffany (ed.), 1982b, *which see.*

ABBOTT, L. R. 1982b. Excavations [at Arthur site], p. 14-38. *In* J. A. Tiffany (ed.), 1982b, *which see.*

ABBOTT, L. R., and J. A. TIFFANY. 1982. Introduction [to Arthur site report], p. 1-7. *In* J. A. Tiffany (ed.), 1982b, *which see.*

ALEX, R. 1970. Small mammal remains [at Broken Kettle West], p. 4-5. *In* D. A. Baerreis [ed.], 1970a, *which see.*

ANDERSON, D. [C.] 1975. Western Iowa Prehistory. Iowa State Univ. Press, Ames, 85 p.

ANDERSON, D. C. 1985. Models of Mill Creek midden formation: Implications for future research. Ptoc. Iowa Acad. Sci. 92:53-57.

ANDERSON, D. C., and H. A. SEMKEN, Jr. (eds.). 1980. The Cherokee Excavations: Holocene Ecology and Human Adaptations in Northwestern Iowa. Academic Press, New York, 277 p.

ANDERSON, D. C., and P. M. WILLIAMS. 1974. Western Iowa proboscidians. Proc. Iowa Acad. Sci. 81:185-191.

ANDERSON, N. C. 1905. A preliminary list of fossil mastodon and mammoth remains in Illinois and Iowa. Augustana Libr. Publ. (Rock Island, Ill.) 5:1-43.

ANDERSON, W. A. 1938. The oldest Iowa tree. Proc. Iowa Acad. Sci. 1938 45:73-74.

AUFFENBERG, W. 1957. A note on an unusually complete specimen of *Dasypus bellus* (Simpson) from Florida. Quart. J. Florida Acad. Sci. 20:233-237.

BAERREIS, D. A. 1969. A preliminary analysis of gastropods from the Mill Creek sites, p. 333-343. *In* D. R. Henning (ed.), 1969, *which see.*

BAERREIS, D. A. [ed.]. 1970a. Environmental archaeology in westetn Iowa. Newsl. Northwest Chapter Iowa Archaeol. Soc. 18:3-15.

BAERREIS, D. A. 1970b. Introduction [to Broken Kettle West], p. 3. *In* D. A. Baerreis [ed.], 1970a, *which see.*

BAERREIS, D. A. 1981. Terrestrial gastropods from the Rainbow site (13PM91), p. 303-314. *In* D. W. Benn (ed.), 1981c, *which see.*

BAERREIS, D. A., and R. A. BRYSON. 1965. Climatic episodes and the dating of the Mississippian cultures. Wisconsin Archeol. 46:203-220.

BAERREIS, D. A., and R. A. BRYSON (eds.). 1967. Climatic change and the Mill Creek culture of Iowa. Arch. Archaeol. 29, 673 p. microcard.

BAIN, H. F. 1897. Relations of the Wisconsin and Kansan drift sheets in central Iowa, and related phenomena. Rept. on Lead, Zinc, Artesian Wells, etc., Iowa Geol. Surv. 6:429-476.

BAIN, H. F. 1898. The Aftonian and pre-Kansan deposits in southwestern Iowa. Proc. Iowa Acad. Sci. 1897 5:86-101.

BAKER, R. G., and K. L. VAN ZANT. 1980. Holocene vegetational reconstruction in northwestern Iowa, p. 123-138. *In* D. C. Anderson and H. A. Semken, Jr. (eds.), 1980, *which see.*

BAKER, R. G., K. L. VAN ZANT, and J. J. DULIAN. 1980. Three late-glacial pollen and plant macrofossil assemblages from Iowa. Palynol. 4:197-203.

BAKER, R. G., and K. A. WALN. 1985. Quaternary pollen records from the Great Plains and central United States, p. 191-203. *In* V. M. Bryant, Jr., and R. G. Holloway (eds.). Pollen Records of Late-Quaternary North American Sediments. Amer. Assoc. Stratigr. Palynol. Found., Dallas, 423 p.

BARBOUR, E. H., and C. B. SCHULTZ. 1937. An early Pleistocene fauna from Nebraska. Amer. Mus. Novitates, 942, 10 p.

BARDWELL, J. 1981. The Paleoecological and Social Significance of the Zooarchaeological Remains from Central Plains Tradition Earthlodges of the Glenwood Locality, Mills County, Iowa. Unpubl. M. A. thesis, Social Studies, Univ. Iowa, Iowa City, 80 p.

BENDER, M. M., R. A. BRYSON, and D. A. BAERREIS. 1973a. University of Wisconsin radiocarbon dates X. Radiocarbon 15:229-239.

BENDER, M. M., R. A. BRYSON, and D. A. BAERREIS. 1973b. University of Wisconsin radiocarbon dates XI. Radiocarbon 15:611-623.

BENDER, M. M., R. A. BRYSON, and D. A. BAERREIS. 1976. University of Wisconsin radiocarbon dates XIII. Radiocarbon 18:125-139.

BENN, D. W. 1980. Hadfields cave: A perspective on Late Woodland culture in northeastern Iowa. Office State Archaeol. [Iowa], Rept. 13, 238 p. text + 196 p. microfiche.

BENN, D. W. (ed.). 1981a. Archaeology of the M.A.D. Sites at Denison, Iowa, 2 Vols. Preliminary draft rept. to Iowa State Historical Dept., Div. Historic Preservation. On deposit, Office State Archaeol. [Iowa]. Pagination irregular.

BENN, D. W. 1981b. Introduciton to the MAD sites investigation, p. I1-I22 + figures and tables 26 p. *In* D. W. Benn (ed.), 1981a, *which see.*

BENN, D. W. (ed.). 1981c. Archaeological Investigations at the Rainbow Site, Plymouth County, Iowa. Rept. Luther College [Decorah, Iowa] Archaeol. Res. Center to Interagency Archaeol. Serv., Denver, 379 p.

BENN, D. W. 1981d. The Rainbow site, stratigraphy, and features, p. 75-153. *In* D. W. Benn (ed.), 1981c, *which see.*

BENN, D. W. 1981e. Paleobotany [of Rainbow site], p. 315-328. *In* D. W. Benn (ed.), 1981c, *which see.*

BETTIS, E. A., III. 1981a. Geology of the MAD sites, p. IIA1-IIA121 + appendix 109 p. *In* D. W. Benn (ed.), 1981a, *which see.*

BETTIS, E. A., III. 1981b. Holocene stratigraphy, geomorphology, and soils of the Rainbow site, p. 10-74. *In* D. W. Benn (ed.), 1981c, *which see.*

BETTIS, E. A., III and D. M. THOMPSON. 1981. Holocene landscape evolution in western Iowa — Concepts, methods and implications for archaeology, p. 1-14. *In* S. F. Anfinson (comp. and ed.). Current directions in Midwestern archaeology: Selected papers from the Mankato conference. Minnesota Archaeol. Soc., Occas. Publ. Minnesota Anthropol. 9, 114 p.

BETTIS, E. A., III and D. M. THOMPSON. 1982a. Part II: The physical system, p. 53-134. *In* E. A. Bettis III and D. M. Thompson, 1982c, *which see.*

BETTIS, E. A., III and D. M. THOMPSON. 1982b. Appendix: Catalog of radiocarbon dates from western Iowa alluvium, p. A1-A23. *In* E. A. Bettis III and D. M. Thompson, 1982c, *which see.*

BETTIS, E. A., III and D. M. THOMPSON. 1982c. Interrelations of Cultural and Fluvial Deposits in Northwest Iowa. Guidebook and Short Papers Prepared for a Field Trip to Plymouth County, April 3-4, 1982. Assoc. Iowa Archeol., 142 p. + [appendix] 23 p.

BOELLSTORFF, J. D. 1973a. Tephrochronology, Petrology, and Stratigraphy of Some Pleistocene Deposits in the Central Plains U.S.A. Unpubl. Ph.D. dissertation, Dept. Geol., Louisiana State Univ. and Agric. and Mechanical College, Baton Rouge, 197 p.

BOELLSTORFF, J. [D.] 1973b. Fission-track ages of Pleistocene volcanic ash deposits in the Central Plains, U.S.A. Isochron/West 8:39-43.

BOELLSTORF[F], J. [D.] 1974. Fission-track ages of Pearlette Family ash beds: Comment. Geology 2:21.

BOELLSTORFF, J. [D.] 1976. The succession of Late Cenozoic volcanic ashes in the Great Plains: A progress report, p. 37-71. *In* C. K. Bayne. Guidebook: 24th annual meeting Midwestern Friends of the Pleistocene. Kansas Geol. Surv., Univ. Kansas, Guideb. Ser. 1, 85 p.

BOELLSTORFF, J. [D.] 1978. North American Pleistocene stages reconsidered in light of probable Pliocene-Pleistocene continental glaciation. Science 202:305-307.

BOWLES, J. B. 1975. Distribution and biogeography of mammals of Iowa. Texas Tech Univ., Mus. Spec. Publ. 9, 184 p.

BRYSON, R. A., and D. A. BAERREIS. 1968. Introduction and project summary [to Mill Creek culture], p. 1-34. *In* D. R. Henning, (ed.), 1968, *which see.*

BRYSON, R. A., and W. M. WENDLAND. 1967. Tentative climatic patterns for some Late Glacial and Post-Glacial episodes in central North America, p. 271-298. *In* W. J. Mayer-Oakes (ed.). Life, land, and water: Proceedings of the 1966 conference on environmental studies of the Glacial Lake Agassiz region. Dept. Anthropol., Univ. Manitoba, Occas. Papers 1, 416 p.

BURT, W. H., and R. P. GROSSENHEIDER. 1976. A Field Guide to the Mammals, Third Edition. Houghton Mifflin Co., Boston, 289 p.

CALVIN, S. 1905. The Aftonian gravels, and their relations to the drift sheets in the region about Afton Junction and Thayer. Proc. Davenport Acad. Sci. 10:18-31.

CALVIN, S. 1909a. Aftonian mammalian fauna. Bull. Geol. Soc. Amer. 20:341-356.

CALVIN, S. 1909b. Present phase of the Pleistocene problem in Iowa. Bull. Geol. Soc. Amer. 20:133-152.

CALVIN, S. 1910. The Aftonian age of the Aftonian mammalian fauna. Proc. Iowa Acad. Sci. 1910 17:177-180.

CALVIN, S. 1911. Aftonian mammalian fauna II. Bull. Geol. Soc. Amer. 22:207-216.

CHAMBERLIN, T. C. 1895a. Chapter 42, Glacial phenomena of North America — *continued*, p. 753-775. *In* J. Geikie. The Great Ice Age and Its Relation to the Antiquity of Man, 3rd Edition. D. Appleton and Co., New York, 850 p.

CHAMBERLIN, T. C. 1895b. The classification of American glacial deposits. J. Geol. 3:270-277.

CHAMBERLIN, T. C. 1896. Editorial. J. Geol. 4:872-876.

CHAPMAN, J. A., and G. A. FELDHAMER (eds.). 1982. Wild Mammals of North America: Biology, Management, and Economics. Johns Hopkins Univ. Press, Baltimore, 1147 p.

CHASE, J. D., W. E. HOWARD, and J. T. ROSEBERRY. 1982. Pocket gophers: Geomyidae, p. 239-255. *In* J. A. Chapman and G. A. Feldhamer (eds.), 1982, *which see.*

CHURCHER, C. S. 1984. *Sangamona*: The furtive deer, p. 316-331. *In* H. H. Genoways and M. R. Dawson (eds.), 1984, *which see.*

CLEMENT, G. M. 1932. Some Pleistocene Mammals of Iowa. Unpubl. M.S. thesis, Dept. Geol., Univ. Iowa, Iowa City, 120 p.

CONDRA, G. E., and E. C. REED. 1950. Correlation of the Pleistocene deposits of Nebraska. Nebraska Geol. Surv. Bull. 15-A, 74 p. (A revision of G. E. Condra, E. C. Reed, and E. D. Gordon. 1947. Correlation of the Pleistocene deposits of Nebraska. Nebraska Geol. Surv. Bull. 15, 73 p.)

CONRAD, L. A., and R. C. KOEPPEN. 1972. An analysis of charcoal from the Brewster site (13CK15), Iowa. Plains Anthropol. 17:52-54.

CRANE, H. R., and J. B. GRIFFIN. 1961. University of Michigan radiocarbon dates VI. Radiocarbon 3:105-125.

DALLMAN, J. E. 1983. A choice of diet: Response to climatic change. Office State Archaeol. [Iowa], Rept. 16, 133 p.

DANIELS, R. B., M. RUBIN, and G. H. SIMONSON. 1963. Alluvial chronology of the Thompson Creek watershed, Harrison County, Iowa. Amer. J. Sci. 261:473-487.

DAVIS, L. C., R. E. ESHLEMAN, and J. PRIOR. 1972. A primary mammoth site with associated fauna in Pottawattamie County, Iowa. Proc. Iowa Acad. Sci. 79:62-65.

DECHERT, H. S. 1968. Paleoecology and Correlation of the "Aftonian" Fauna from Harrison and Monona Counties, Iowa. Unpubl. M.S. thesis, Geol. Dept., Univ. Iowa, Iowa City, 85 p.

DELAVAN, F. 1926. Some recent finds of remains of the extinct ground sloth in southwest Iowa. Proc. Iowa Acad. Sci. 1926 33:203-205.

DORT, W., Jr., and J. K. JONES, Jr. (eds.). 1970. Pleistocene and Recent Environments of the Central Great Plains. (Dept. Geol., Univ. Kansas, Spec. Publ. 3.) Univ. Press Kansas, Lawrence, 433 p.

DULIAN, J. J. 1975. Paleocecology of the Brayton Local Biota, Late Wisconsinan of Southwestern Iowa. Unpubl. M.S. thesis, Geol. Dept., Univ. Iowa, Iowa City, 50 p.

DUVICK, D. N., and T. J. BLASING. 1983. Iowa's oldest oaks. Proc. Iowa Acad. Sci. 90:32-34.

ESHELMAN, R. E. 1971. The Paleoecology of Willard Cave, Delaware County, Iowa. Unpubl. M.S. thesis, Geol. Dept., Univ. Iowa, Iowa City, 72 p.

EVERNDEN, J. F., D. E. SAVAGE, G. H. CURTIS, and G. T. JAMES. 1964. Potassium-argon dates and the Cenozoic mammalian chronology of North America. Amer. J. Sci. 262:145-198.

FALK, C. R. 1981. Vertebrate remains [at Rainbow site], p. 223-259. *In* D. W. Benn (ed.), 1981c, *which see.*

FARRAR, D. R., D. M. ROOSA, and J. C. PRIOR. 1985. Iowa's Loess Hills — A national treasure. Proc. Iowa Acad. Sci. 92:157-158.

FAY, L. P. 1978a. Catalog of Quaternary palynologic and vertebrate localities in Iowa. Proc. Iowa Acad. Sci. 85:35-38.

FAY, L. P. 1978b. Mammals of the Garrett Farm and Pleasant Ridge Local Biotas (Holocene), Mills County, Iowa. Unpubl. M.S. thesis, Geol. Dept., Univ. Iowa, Iowa City, 54 p.

FAY, L. P. 1980. Mammals of the Garrett Farm and Pleasant Ridge local

biotas (Holocene), Mills County, Iowa [abstr.]. Amer. Quaternary Assoc., Abstr. and Program, Sixth Biennial Meet., Orono, Maine, p. 74-75.

FISHER, A. K., W. D. FRANKFORTER, J. A. TIFFANY, S. J. SCHERMER, and D. C. ANDERSON. 1985. Turin: A Middle Atchaic burial site in western Iowa. Plains Anthropol. 30:195-218.

FLINT, R. F. 1971. Glacial and Quaternary Geology. John Wiley and Sons, New York, 892 p.

FRANKFORTER, W. D. 1957. A probable Illinoian till in western Iowa [abstr.]. Proc. Nebraska Acad. Sci. 67th Annual Meet. p. 12.

FRANKFORTER, W. D. 1969. Faunal study of large ruminants from Mill Creek culture sites in northwest Iowa, p. 286-301. *In* D. R. Henning (ed.), 1969, *which see.*

FRANKFORTER, W. D. 1971. The Turin local fauna, evidence for the medial Pleistocene age of the original "Aftonian" vertebrate fauna in western Iowa [abstr.]. Proc. Nebraska Acad. Sci. 81st Annual Meet. p. 48-49.

FRANKFORTER, W. D. n.d. The Turin Local Fauna, Evidence that the Original "Aftonian" Fauna of Western Iowa is Middle Pleistocene [manuscript, 1978?]. 27 p.

FRYE, J. C., A. SWINEFORD, and A. B. LEONARD. 1948. Correlation of Pleistocene deposits of the Central Great Plains with the glacial section. J. Geol. 56:501-525.

FULMER, D. W. 1974. A Central Plains Earthlodge: 13ML124. Unpubl. M.A. thesis, Dept. Anthropol., Univ. Iowa, Iowa City, 98 p.

GENOWAYS, H. H., and M. R. DAWSON (eds.). 1984. Contributions in Quaternary vertebrate paleontology: A volume in memorial to John E. Guilday. Spec. Publ. Carnegie Mus. Nat. Hist. 8, 538 p.

GOSLIN, R. M. 1951. Evidence of the occurrence of the rice rat in prehistoric Indian village sites in Ohio. Bull. Ohio Indian Relic Collectors Soc. [now Ohio Archaeol.] 26:19-22.

GRAHAM, R. W. 1976. Late Wisconsin mammalian faunas and environmental gradients of the eastern United States. Paleobiology 2:343-350.

GRAHAM, R. W. 1979. Paleoclimates and late Pleistocene faunal provinces in North America, p. 49-69. *In* R. L. Humphrey and D. J. Stanford (eds.). Pre-Llano Cultures of the Americas: Paradoxes and Possibilities. Anthropol. Soc. Washington, Washington, DC, 150 p.

GRAHAM, R. W., and H. A. SEMKEN, [Jr.] 1976. Paleoecological significance of the short-tailed shrew (*Blarina*), with a systematic discussion of *Blarina ozarkensis*. J. Mamm. 57:433-449.

GRAHAM, R. W., H. A. SEMKEN, Jr., and M. A. GRAHAM (eds.). In press. Late Quaternary mammalian biogeography and environments of the Great Plains and Prairies. Illinois State Mus., Scientific Papers Ser.

GRAYSON, D. K. 1981. A critical view of the use of archaeological vertebrates in paleoenvironmental reconstruction. J. Ethnobiol. 1:28-38.

GUILDAY, J. E. 1955. Animal remains from an Indian village site, Indiana County, Pennsylvania. Pennsylvania Archaeol. 25:142-147.

GUTHRIE, R. D. 1968. Paleoecology of the large-mammal community in interior Alaska during the late Pleistocene. Amer. Midland Nat. 79:346-363.

GUTHRIE, R. D. 1984. Mosaics, allelochemics and nutrients: An ecological theory of late Pleistocene megafaunal extinctions, p. 259-298. *In* P. S. Martin and R. G. Klein (eds.), 1984, *which see.*

HALL, E. R. 1981. The Mammals of North America, Second Edition, two volumes. John Wiley & Sons, New York, 1181 p. + [indices] 90 p.

HARINGTON, C. R. 1984. Mammoths, bison and time in North America, p. 299-309. *In* W. C. Mahaney (ed.). Quaternary Dating Methods. Elsevier Sci. Publishers, Amsterdam, 431 p.

HAY, O. P. 1914. The Pleistocene mammals of Iowa. Annual Rept. 1912, Iowa Geol. Surv. 23:1-662.

HAY, O. P. 1925. On the correlation of certain Pleistocene deposits and their fossils. J. Washington Acad. Sci. 15:239-246.

HENNING, D. R. (ed.). 1968. Climatic change and the Mill Creek culture of Iowa, Part I, p. 1-191. J. Iowa Archeol. Soc. 15. [Republication of chapters I-III, D. A. Baerreis and R. A. Bryson (eds.), 1967, *which see.*]

HENNING, D. R. (ed.). 1969. Climatic change and the Mill Creek culture of Iowa, Part II, p. 192-358. J. Iowa Archeol. Soc. 16. [Republication of chapters IV-XI, D. A. Baerreis and R. A. Bryson (eds.), 1967, *which see.*]

HENNING, D. R., A. E. HENNING, and D. A. BAERREIS. 1968. 1963 excavations in the Mill Creek sites, p. 35-106. *In* D. R. Henning (ed.), 1968, *which see.*

HENNING, D. [R.], and E. [R.] HENNING. 1982. Mill Creek and Great Oasis sites, p. 15-25. *In* E. A. Bettis III and D. M. Thompson, 1982c, *which see.*

HENNING, E. [R.], and D. [R.] HENNING. 1982. Great Oasis - Mill Creek interrelationships, p. 10-14. *In* E. A. Bettis III and D. M. Thompson, 1982c, *which see.*

HIBBARD, C. W. 1948. [Comment], p. 662. *In* E. H. Colbert (chairman). Discussion [to symposium on], Pleistocene of the High Plains. Bull Geol. Soc. Amer. 59:620-626.

HOFFMAN, R. S., and J. K. JONES, Jr. 1970. Influence of late-glacial and post-glacial events on the distribution of Recent mammals on the Northern Great Plains, p. 355-394. *In* W. Dort, Jr., and J. K. Jones, Jr. (eds.), 1970, *which see.*

HOTOPP, J. A. 1978a. A Reconsideration of Settlement Patterns, Structures, and Temporal Placement of the Central Plains Tradition in Iowa. Unpubl. Ph.D. dissertation, Education, Univ. Iowa, Iowa City, 286 p.

HOTOPP, J. [A.] 1978b. Glenwood: A contemporary view, p. 109-133. *In* D. J. Blakeslee (ed.). The Central Plains Tradition. Office State Archaeol. [Iowa], Rept. 11, 166 p.

HOTOPP, J. [A.], R. S. RHODES II, and H. A. SEMKEN, Jr. 1975. Waubonsie Watershed Survey. Rept. Office State Archaeol. [Iowa] to Natl. Park Serv., Lincoln, 80 p.

HOYER, B. E. 1980a. Geomorphic History of the Little Sioux River Valley. Fall Field Trip [Guideb.], September 20 & 21, 1980. GSI [= Geol. Soc. Iowa], [Iowa Geol. Surv.], 94 p.

HOYER, B. E. 1980b. The geology of the Cherokee Sewer site, p. 21-66. *In* D. C. Anderson and H. A. Semken, Jr. (eds.), 1980, *which see.*

HUDAK, C. M. 1984. Paleoecology of an early Holocene faunal and floral assemblage from the Dows local biota of north-central Iowa. Quaternary Res. 21:351-368.

IVES, J. C. 1962. Mill Creek pottery. J. Iowa Archeol. Soc. 11(3):1-59.

JAMES, W. R., and H. NICHOLS. 1969. Pollen analysis of materials from the Phipps, Kimball, and Wittrock sites in Iowa, p. 302-317. *In* D. R. Henning (ed.), 1969, *which see.*

JENKINS, J. T., Jr. 1972. The Pleistocene Geology and Paleoecology of the Fremont County Quarry, Fremont County, Iowa. Unpubl. M.S. thesis, Geol. Dept., Univ. Iowa, Iowa City, 55 p.

JONES, C. A., J. R. CHOATE, and H. H. GENOWAYS. 1984. Phylogeny and paleobiogeography of short-tailed shrews (genus *Blarina*), p. 56-148. *In* H. H. Genoways and M. R. Dawson (eds.), 1984, *which see.*

JONES, J. K., Jr., D. M. ARMSTRONG, R. S. HOFFMANN, and C. JONES. 1983. Mammals of the Northern Great Plains. Univ. Nebraska Press, Lincoln, 379 p.

JOHNSON, P. C. 1972. Mammalian Remains Associated with Nebraska Phase Earth Lodges in Mills County, Iowa. Unpubl. M.S. thesis, Geol. Dept., Univ. Iowa, Iowa City, 71 p.

KAY, G. F. 1928. History of the Investigations and Classificaitons of the Pleistocene Deposits of Iowa. Iowa Geol. Surv., Iowa City, 67 p. (Also published in G. F. Kay and E. T. Apfel, 1929, Chapter 3, p. 70-133, *which see.*)

KAY, G. F., and E. T. APFEL. 1929. The pre-Illinoian Pleistocene geology of Iowa. Annual Rept. 1928, Iowa Geol. Surv. 34:1-304.

KAY, G. F., and J. B. GRAHAM. 1943. The Illinoian and post-Illinoian Pleistocene geology of Iowa. Annual Rept. 1940 and 1941, Iowa Geol. Surv. 38:1-262.

KILDEE, H. H., (chairman). 1935. The Second Report. Rept. Iowa State Planning Board to Natl. Resources Board, Washington, D.C., 226 p.

KING, F. B., and R. W. GRAHAM. 1981. Effects of ecological and paleoecological patterns on subsistence and paleoenvironmental reconstructions. Amer. Antiquity 46:128-142.

KLIPPEL, W. E., and P. W. PARMALEE. 1984. Armadillos in North American late Pleistocene contexts, p. 149-160. *In* H. H. Genoways and M. R. Dawson (eds.), 1984, *which see.*

KORTH, W. W. 1979. Taphonomy of microvertebrate fossil assemblages. Ann. Carnegie Mus. 48:235-285.

KRIEGER, A. D. (comp.). 1956. Early man, p. 449-452. *In* C. W. Meighan (ed.). Notes and news. Amer. Antiquity 21:440-452.

KURTÉN, B. 1979. The stilt-legged deer *Sangamona* of the North-American Pleistocene. Boreas 8:313-321.

KURTÉN, B., and E. ANDERSON. 1980. Pleistocene Mammals of North America. Columbia Univ. Press, New York, 442 p.

LAMPE, R. P., and J. B. BOWLES. 1985. Annotated checklist of the mammals of the Loess Hills of western Iowa. Proc. Iowa Acad. Sci. 92:176-179.

LAMPE, R. P., J. B. BOWLES, and R. SPENGLER. 1981. First state

record of Richardson's ground squirrel in Iowa. Prairie Nat. 13:94-96.
LEHMER, D. J. 1970. Climate and culture history in the Middle Missouri Valley, p. 117-129. *In* W. Dort, Jr., and J. K. Jones, Jr. (eds.), 1970, *which see.*
LEIDY, [J.] 1870. [Untitled remarks July 12th.] Proc. Acad. Nat. Sci. Philadelphia 1870 [22:]73.
LUGN, A. L. 1934. Part I: Outline of Pleistocene geology of Nebraska, p. 319-356. *In* A. L. Lugn and C. B. Schultz, 1934, *which see.*
LUGN, A. L., and C. B. SCHULTZ. 1934. The geology and mammalian fauna of the Pleistocene of Nebraska. Bull. [Univ.] Nebraska State Mus. 1:319-393.
LUNDELIUS, E. L., Jr., R. W. GRAHAM, E. ANDERSON, J. [E.] GUILDAY, J. A. HOLMAN, D. W. STEADMAN, and S. D. WEBB. 1983. Terrestrial vertebrate faunas, p. 311-353. *In* H. E. Wright, Jr., and S. C. Porter (eds.). Late-Quaternary Environments of the United States, Vol. 1, The Late Pleistocene. Univ. Minnesota Press, Minneapolis, 407 p.
McDONALD, H. G., and D. C. ANDERSON. 1983. A well-preserved ground sloth (*Megalonyx*) cranium from Turin, Monona County, Iowa. Proc. Iowa Acad. Sci. 90:134-140.
McGEE, W. J. 1887. Ovibos cavifrons from the loess of Iowa. Amer. J. Sci. 3rd ser. 34 (vol. whole number 134):217-220.
McKUSICK, M. 1964. Men of Ancient Iowa as Revealed by Archeological Discoveries. Iowa State Univ. Press, Ames, 260 p.
MANGERUD, J., S. T. ANDERSEN, B. E. BERGLUND, and J. J. DONNER. 1974. Quaternary stratigraphy of Norden, a proposal for terminology and classification. Boreas 3:109-127.
MARTIN, P. S., and R. G. KLEIN (eds.). 1984. Quaternary Extinctions: A Prehistoric Revolution. Univ. Arizona Press, Tucson, 892 p.
MARTIN, P. S., and H. E. WRIGHT, Jr. (eds.). 1967. Pleistocene Extinctions: The Search for a Cause. Yale Univ. Press, New Haven, 453 p.
MEAD, J. I., and D. J. MELTZER. 1984. North American late Quaternary extinctions and the radiocarbon record, p. 440-450. *In* P. S. Martin and R. G. Klein (eds.), 1984, *which see.*
MEAD, J. I., and D. J. MELTZER (eds.). 1985. Environments and Extinctions: Man in Late Glacial North America. Center Study Early Man, Univ. Maine, Orono, 209 p.
MONCRIEF, N. D., J. R. CHOATE, and H. H. GENOWAYS. 1982. Morphometric and geographic relationships of short-tailed shrews (genus *Blarina*) in Kansas, Iowa, and Missouri. Ann. Carnegie Mus. 51:157-180.
NOVACEK, J. M., D. M. ROOSA, and W. P. PUSATERI. 1985. The vegetation of the Loess Hills landform along the Missouri River. Proc. Iowa Acad. Sci. 92:199-212.
OSBORN, H. F. 1924. Additional generic and specific stages in the evolution of the Proboscidea. Amer. Mus. Novitates, 154, 5 p.
PAULSON, G. R., and B. B. MILLER. 1983. Two fossil assemblages associated with the Hartford ash from Little Sioux, Iowa. Abstr. with Programs, Geol. Soc. Amer. 15:659.
PRIOR, J. C. 1976. A regional guide to Iowa landforms. Iowa Geol. Surv., Educ. Ser. 3, 72 p.
PURDUE, J. R., and B. W. STYLES. In press. Changes in the mammalian fauna of Illinois and Missouri during the late Pleistocene and Holocene. *In* R. W. Graham et al. (eds.), in press, *which see.*
PYLE, K. B. 1980. The Cherokee large mammal fauna, p. 171-196. *In* D. C. Anderson and H. A. Semken, Jr. (eds.), 1980, *which see.*
PYLE, K. B. 1981. Faunal remains from the MAD sites (13CF101 and 13CF102), Crawford County, Iowa, p. VI1-VI31 + figures and tables 31 p. *In* D. W. Benn (ed.), 1981a, *which see.*
REED, E. C., and V. H. DREESZEN. 1965. Revision of the classification of the Pleistocene deposits of Nebraska. Nebraska Geol. Surv. Bull. 23, 65 p.
REICH, L. M. 1981. Microtus pennsylvanicus. Mamm. Species 159, 8 p.
RHODES, R. S., II. 1984. Paleoecology and regional paleoclimatic implications of the Farmdalian Craigmile and Woodfordian Waubonsie mammalian local faunas, southwestern Iowa. Illinois State Mus., Rept. Invest. 40, 51 p.
RHODES, R. S., II and H. A. SEMKEN, Jr. 1976. Paleontological Investigations within the Waubonsie Creek Watershed, Iowa. [NTIS PB-260 767.] Rept. Geol. Dept., Univ. Iowa to Natl. Park Serv., Denver, 48 p.
RUHE, R. V. 1969. Quaternary Landscapes in Iowa. Iowa State Univ. Press, Ames, 255 p.
RUPPE, R. J. 1959. Archeology at SUI. J. Iowa Archeol. Soc. 9:9-11.
SATORIUS-FOX, M. R. 1982. Paleoecological analysis of micromammals from the Schmidt site, a Central Plains Tradition village in Howard County, Nebraska. Div. Archeol. Res., Dept. Anthropol., Univ. Nebraska, Tech. Rept. 82-13, 87 p.
SAVAGE, D. E. 1951. Late Cenozoic vertebrates of the San Francisco Bay region. Univ. California Publ., Bull. Dept. Geol. Sci. 28:215-314.
SCHULTZ, C. B. 1934. Part II: The Pleistocene mammals of Nebraska, p. 357-393. *In* A. L. Lugn and C. B. Schultz, 1934, *which see.*
SCHULTZ, C. B., and J. M. HILLERUD. 1977. The antiquity of *Bison latifrons* (Harlan) in the Great Plains of North America. Trans. Nebraska Acad. Sci. 4:103-116.
SCHULTZ, C. B., L. D. MARTIN, L. G. TANNER, and R. G. CORNER. 1978. Provincial land mammal ages for the North American Quaternary. Trans. Nebraska Acad. Sci. 5:59-64.
SCHULTZ, C. B., and T. M. STOUT. 1948. Pleistocene mammals and terraces in the Great Plains. Bull. Geol. Soc. Amer. 59:553-588.
SCHWARTZ, C. W., and E. R. SCHWARTZ. 1981. The Wild Mammals of Missouri, Revised Edition. Univ. Missouri Press, Columbia, 356 p.
SEMKEN, H. A., [Jr.] 1971. Small mammal remains from the Wittrock Mill Creek culture site, p. 109-113. *In* M. McKusick (ed.). Prehistoric investigations. Office State Archaeol. [Iowa], Rept. 3, 144 p.
SEMKEN, H. A., Jr. 1980. Holocene climatic reconstructions derived from the three micromammal bearing cultural horizons of the Cherokee Sewer site, northwestern Iowa, p. 67-99. *In* D. C. Anderson and H. A. Semken, Jr. (eds.), 1980, *which see.*
SEMKEN, H. A., Jr. 1981. Descriptive analysis of the rodent cranial elements collected from the Rainbow site (13PM91), Plymouth County, Iowa, p. 260-281. *In* D. W. Benn (ed.), 1981c, *which see.*
SEMKEN, H. A., Jr. 1982. Mammalian remains [from Arthur site], p. 119-132. *In* J. A. Tiffany (ed.), 1982b, *which see.*
SEMKEN, H. A., Jr. 1983. Holocene mammalian biogeography and climatic change in the eastern and central United States, p. 182-207. *In* H. E. Wright, Jr. (ed.). Late-Quaternary Environments of the United States, Vol. 2, The Holocene. Univ. Minnesota Press, Minneapolis, 277 p.
SEMKEN, H. A., Jr. 1984. Paleocology of a late Wisconsinan/Holocene micromammal sequence in Peccary Cave, northwestern Arkansas, p. 405-431. *In* H. H. Genoways and M. R. Dawson (eds.), 1984, *which see.*
SEMKEN, H. A., Jr., and C. R. FALK. In press. Late Pleistocene/Holocene mammalian faunas and environmental changes on the northern Plains of the United States. *In* R. W. Graham et al. (eds.), in press, *which see.*
SHELFORD, V. E. 1963. The Ecology of North America. Univ. Illinois Press, Urbana, 610 p.
SHIMEK, B. 1908. Aftonian sands and gravel in western Iowa [correspondence to the editor]. Science n.s. 28:923.
SHIMEK, B. 1909. Aftonian sands and gravels in western Iowa. Bull. Geol. Soc. Amer. 20:399-408.
SHIMEK, B. 1910a. Evidence that the fossiliferous gravel and sand beds of Iowa and Nebraska are Aftonian. Bull. Geol. Soc. Amer. 21:119-140.
SHIMEK, B. 1910b. Geology of Harrison and Monona Counties. Annual Rept. 1909, Iowa Geol. Surv. 20:271-485.
SHIMEK, B. 1910c. The Pleistocene of the Missouri Valley. Science n.s. 31:75-76.
SHIMEK, B. 1911. The prairies. Contrib. Lab. Nat. Hist. State Univ. Iowa 6(2):169-240 + 14 plates.
SIMPSON, G. G. 1980. Splendid Isolation: The Curious History of South American Mammals. Yale Univ. Press, New Haven, 266 p.
SPARGO, L. n.d. Oneota Subsistence Strategy in Northwest Iowa: The Milford Site. [manuscript, 1985].
STAAB, M. L. 1970. Large mammal remains [at Broken Kettle West], p. 3-4. *In* D. A. Baerreis [ed.], 1970a, *which see.*
TAYLOR, R. E. 1980. Radiocarbon dating of Pleistocene bone: Toward criteria for the selection of samples. Radiocarbon 22:969-979.
THOMPSON, D. M., and E. A. BETTIS III. 1980. Archeology and Holocene landscape evolution in the Missouri drainage of Iowa. J. Iowa Archeol. Soc. 27:1-60.
TIFFANY, J. A. 1981. A compendium of radiocarbon dates for Iowa archaeological sites. Plains Anthropol. 26:55-73. [Reprint with author's corrections.]
TIFFANY, J. A. 1982a. Interpretive summary [of Arthur site], p. 188-199. *In* J. A. Tiffany (ed.), 1982b, *which see.*

TIFFANY, J. A. (ed.). 1982b. A preliminary report on the Arthur site, East Okoboji Lake, Iowa. Office State Archaeol. [Iowa], Res. Papers Ser. 7(1), 305 p.
TIFFANY, J. A. 1982c. Chan-ya-ta: A Mill Creek village. Office State Archaeol. [Iowa], Rept. 15, 110 p. text + 388 p. microfiche.
TOMICH, P. Q. 1982. Ground squirrels: *Spermophilus beecheyi* and allies, p. 192-208. *In* J. A. Chapman and G. A. Feldhamer (eds.), 1982, *which see.*
UDDEN, J. A. 1903. Geology of Mills and Fremont Counties. Annual Rept. 1902, Iowa Geol. Surv. 13:123-183.
VAN ZANT, K. [L.] 1979. Late glacial and postglacial pollen and plant macrofossils from Lake West Okoboji, northwestern Iowa. Quaternary Res. 12:358-380.
VOORHIES, M. R. 1969. Taphonomy and population dynamics of an early Pliocene vertebrate fauna, Knox County, Nebraska. Univ. Wyoming Contrib. Geol., Spec. Paper 1, 69 p.
WEGNER, S. A. 1979. Analysis of seed remains from the Chan-ya-ta site (13BV1), a Mill Creek village in N.W. [sic] Iowa. South Dakota Archaeol. 3:1-80.
WENDLAND, W. M. 1978. Holocene man in North America: The ecological setting and climatic background. Plains Anthropol. 23:273-287.
WENDLAND, W. M. 1980. Holocene climatic reconstructions on the Prairie Peninsula, p. 139-148. *In* D. C. Anderson and H. A. Semken, Jr. (eds.), 1980, *which see.*
WENDLAND, W. M., and R. A. BRYSON. 1974. Dating climatic episodes of the Holocene. Quaternary Res. 4:9-24.
WOLFF, R. G. 1973. Hydrodynamic sorting and ecology of a Pleistocene mammalian assemblage from California (U.S.A.). Palaeogeogr. Palaeoclimatol. Palaeoecol. 13:91-101.
WOOD, H. E., 2nd, R. W. CHANEY, J. CLARK, E. H. COLBERT, G. L. JEPSEN, J. B. REESIDE, Jr., and C. STOCK. 1941. Nomenclature and correlation of the North American continental Tertiary. Bull. Geol. Soc. Amer. 52:1-48.
WORMINGTON, H. M. [1957.] Ancient man in North America. Denver Mus. Nat. Hist., Popular Ser. 4, 322 p.

APPENDIX A:
Alphabetical List of Scientific Names of All Mammals Mentioned

Scientific names generally follow those of Hall (1981); vernacular names generally follow Kurtén and Anderson (1980). A "*" indicates an extinct taxon.

*"*Aftonius calvini* Hay"	(archaic binomen, probably *Euceratherium collinium* Furlong & Sinclair)
*"*Alces shimeki* Hay"	a moose (archaic binomen, modern assignment unknown)
Antilocapra americana (Ord)	pronghorn
Artiodactyla	deer, buffalo, camel, antelope, peccary, etc.
Bison	
B. bison (Linnaeus)	American buffalo
B. latifrons (Harlan)	giant bison
Blarina	short-tailed shrew
B. brevicauda (Say)	
B. b. brevicauda (Say)	the large semispecies of *B. brevicauda*
B. b. kirtlandi Bole & Moulthrop	a subspecies in the semispecies *B. b. brevicauda*
B.b. talpoides (Gapper)	the small semispecies of *B. brevicauda*
B. carolinensis (Bachman)	
B. hylophaga Elliot	
**Camelops* sp.	New World camel
Canis	
C. familiaris Linnaeus	domestic dog
C. latrans Say	coyote
C. lupus Linnaeus	grey wolf
Castor canadensis Kuhl	beaver
**Castoroides ohioensis* Foster	giant beaver
Carnivora	bear, wolf, panther, mink, skunk, etc.
**Cervalces scotti* (Lydekker)	stag-moose
Cervidae	deer, elk, moose, etc.
Cervus elaphus Linnaeus	wapiti (= American elk)
Chiroptera	bat
Clethrionomys gapperi (Vigors)	boreal redback vole
Cryptotis parva (Say)	least shrew
Cynomys ludovicianus (Ord)	black-tailed prairie dog
Dasypus	
**D. bellus* (Simpson)	beautiful armadillo
D. novemcinctus Linnaeus	nine-banded armadillo
Didelphis sp.	opossum
Edentata	sloth, armadillo, etc.
Eptesicus fuscus (Palisot de Beauvois)	big brown bat
**Equus* sp.	one-toed horse (only New World forms became extinct)
Erethizon dorsatum (Linnaeus)	porcupine
**Euceratherium collinium* Furlong & Sinclair	shrub-ox
Eutamias minimus (Bachman)	least chipmunk
Felis concolor Linnaeus	cougar
Geomys bursarius (Shaw)	Plains pocket gopher
**Glossotherium harlani* (Owen) (variously *"Mylodon"* or *"Paramylodon"*)	Harlan's ground sloth
Gulo gulo (Linnaeus)	wolverine
**"Hipparion gratum* Leidy"	an extinct three-toed horse [archaic binomen, probably *Pseudhipparion gratum* (Leidy)]
Homo sapiens Linnaeus	modern human
Insectivora	shrew, mole, etc.
Lagomorpha	rabbit, hare, pica, etc.
Lasiurus cinereus (Palisot de Beauvois)	hoary bat
Leporidae	rabbits and hares
Lepus townsendii Bachman	white-tailed jack rabbit
Lutra canadensis (Schreber)	river otter
Lynx	
L. canadensis Kerr	Canada lynx
L. rufus (Schreber)	bobcat
**Mammut americanum* (Kerr)	American mastodon
**Mammuthus jeffersonii* (Osborn)	Jefferson's mammoth
Marmota monax Linnaeus	woodchuck
Martes	
M. americana (Turton)	pine martin
M. pennanti (Erxleben)	fisher
**Megalonyx jeffersonii* (Desmarest)	Jefferson's ground sloth
Mephitis mephitis (Schreber)	striped skunk
Microsorex hoyi (Baird)	pigmy shrew (= *Sorex hoyi* of others)
Microtus	
M. (Pedomys) ochrogaster (Wagner)	prairie vole
M. pennsylvanicus (Ord)	meadow vole
M. (Pitymys) pinetorum (Le Conte)	woodland vole

M. xanthognathus (Leach)	yellow-cheeked vole
Mus musculus Linnaeus	house mouse
Mustela vison Schreber	mink
*"*Neohipparion gratum*? Leidy"	(see *Hipparion gratum*)
Neotoma	
N. floridana (Ord)	eastern woodrat
N. micropus Baird	southern Plains woodrat
Odocoileus	
O. hemionus (Rafinesque)	mule deer
O. virginianus (Zimmerman)	white-tailed deer
Ondatra zibethicus (Linnaeus)	muskrat
Onychomys leucogaster (Wied-Neuwied)	northern grasshopper mouse
Oryzomys palustris (Harlan)	marsh rice rat
Ovibos moschatus (Zimmerman)	muskox
Panthera sp.	lion and jaguar
Perognathus	
P. flavescens Merriam	Plains pocket mouse
P. hispidus Baird	hispid pocket mouse
Perissodactyla	horse, rhinoceros, tapir, etc.
Peromyscus	
P. leucopus (Rafinesque)	white-footed mouse
P. maniculatus (Wagner)	deer mouse
Phenacomys intermedius Merriam	heather vole
**Platygonus* sp.	extinct peccary
Proboscidea	elephant, mammoth, mastodon, etc.
Procyon lotor (Linnaeus)	raccoon
Rangifer sp.	caribou
Rattus norvegicus (Berkenhout)	Norway rat
Reithrodontomys megalotis (Baird)	western harvest mouse
Rodentia	rodents - mouse, vole, lemming, gopher, squirrel, beaver, etc.
**Sangamona fugitiva* Hay	stilt-legged deer
Scalopus aquaticus (Linnaeus)	eastern mole
Sciurus	
S. carolinensis Gmelin	grey squirrel
S. niger Linnaeus	fox squirrel
Sorex	
S. arcticus Kerr	arctic shrew
S. cinereus Kerr	masked shrew (includes *S. haydeni* Baird)
S. palustris Richardson	water shrew
Spermophilus	
S. franklinii (Sabine)	Franklin's ground squirrel
S. richardsonii (Sabine)	Richardson's ground squirrel
S. tridecemlineatus (Mitchell)	thirteen-lined ground squirrel
**Stegomastodon mirificus* (Leidy)	wonderful stegomastodon
Sylvilagus sp.	rabbit
**Symbos cavifrons* (Leidy)	bonnet-horned muskox
Synatomys	
S. borealis (Richardson)	northern bog lemming
S. cooperi Baird	southern bog lemming
Tamias striatus (Linnaeus)	eastern chipmunk
Tamiasciurus hudsonicus (Erxleben)	red squirrel
Taxidea taxus (Schreber)	badger
Thomomys talpoides (Richardson)	northern pocket gopher
Urocyon cinereoargenteus (Schreber)	grey fox
Ursus americanus Pallas	black bear
Vulpes	
V. velox (Say)	swift fox
V. vulpes (Linnaeus)	red fox
Zapus hudsonius (Zimmermann)	meadow jumping mouse